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Usage of Agricultural Intensification Practices by Smallholder Farmers in Kenyan Rapidly Developing Dry Areas

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Abstract
Developing countries, Kenya included are mostly affected by food problems and poverty as a result of high dependence on agriculture. In Kenya agriculture contributes to 27.3% of the Gross Domestic Product. Agriculture in Kenya is dominated by smallholder farmers, whose production is hampered by climate variability, declining land sizes and low agricultural technologies. Agricultural intensification is aimed at solving the problem of low agricultural productivity and poverty through increasing farm output per unit land area. Makueni and Nyando Sub-County were considered as hotspots of climate change by CCAFS. A total of 320 households were sampled from the two sub-counties. From the scope farmers were engaged in 16 agricultural intensification practices, some practices were substitutes others complementary so they were highly correlated. Principal Component Analysis (PCA) was then used to group them into clusters called principal components. PCA helped in creating levels of agricultural intensifications. From the results, the number of components (Levels of agricultural intensification) of users was ranging from one to five. That is from low users of strategy 1, partial users of 2, 3 and 4 to full users of 5. The result revealed that 56% of farmers used 5 sets of strategies while 31%, 8%, 3% and 1% of farmers' used 4, 3, 2 and 1 levels of agricultural intensification practices respectively. The results implied that there was need for smallholder farmers to increase agricultural intensification which leads to improved smallholder farmers livelihood outcomes and helps in building their resilience to harsh climatic conditions.
Keywords: Agricultural intensification practices, Kenya, Principal Component Analysis, Smallholder farmer
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1. Introduction

Agriculture in Sub-Saharan Africa (SSA) is considered one of the greatest sector as most smallholder farmers in these regions derive their livelihood through crop and livestock production (OECD/FAO, 2016). Agriculture contributes 25% on average of SSA's GDP employing close to 60% African labour force (Delve *et al*., 2016). The uptake of agricultural improved technology has been low in SSA compared to other regions leading to low yield. In Kenya, Smallholder farmers are the major agricultural producers, yet they remain food insecure and economically poor (Muriithi *et al*., 2009). Livelihood of smallholder farmers in rural areas are based majorly on cultivation of crops and livestock keeping (Ulrich *et al*., 2012). Smallholder farmers produce cereals, legumes, horticulture, industrial crops, aquaculture, apiculture, as well as rearing livestock (KNBS, 2016). According to Wang'ombe and Dijk, (2013), the most important food crop grown in Kenya by most smallholder farmers is maize followed by potatoes which contributes 32% overall dietary consumption. Smale and Olwande, (2014) found that most farmers grow hybrid maize varieties as they have long experience with the seed.

The number of livestock, amount and quality of land a smallholder farmer controls in rural area is wealth and major assets they depend on in generating food and cash incomes (Marenya and Barrett, 2005). According to Moebius *et al*. (2014), soil which supports crop growth has been degraded in most rural areas due to intensive use, erosion, low inputs and poor management by the people. Smallholder farmers in Kenya are much vulnerable to climate change as the country highly depends on rain-fed agriculture, technology adoption is very low and infrastructure and markets are poorly developed (Bryan *et al*., 2013). In most part of the country especially the two sub-counties Makueni and Nyando, which were picked by Climate Change, Agriculture and Food Security (CCAFS) the rainfall pattern is bimodal and there is increasing frequent dry spells leading to crop failures and death of livestock especially because they are semi-arid areas which on average receives low annual rainfall of between 800mm to 400mm (GoK, 2010; GoK, 2013; Silvia *et al*., 2015). Mixed farming assist in improving food security of the households in the two sites as in time of crop failure, failed crop field becomes an option as fodder for livestock.

Most studies have been conducted in Kenya on agricultural intensification but concentrate more on highly productive regions (Smale and Olwande, 2014; Samdup *et al*., 2010; Shiferaw *et al*., 2014). In Arid and Semi-arid areas, livestock production is the major research concern ignoring smallholder farmers practicing mixed farming as a way of livelihood, to them as the farm plots are being disintegrated to smaller portions, they can hardly afford to keep many livestock and cannot move from place to place to search for pasture. The essential part of increasing agricultural productivity to improve smallholder resilience to harsh climatic condition is to develop and spread the new agricultural technology (Glover *et al*., 2019). Adaptation actions should be taken for the most vulnerable to harsh climatic change as farmers in these regions live in future seasonal uncertainties (Campbell et al., 2016). Bringing new land into cultivation is becoming increasingly constrained due to rising population pressure, competition for land from other human activities such as urbanization, and the need to protect remaining uncultivated areas such as forests for carbon storage and preservation of the environment (Kassie et al., 2015).
Understanding how smallholder farmers strategies on the use agricultural intensification practices which will enable them to cope with the rapidly changing climate condition is important to the designing of policies advising them on the best practices they can uptake. This will go a long way in addressing Sustainable Development Goals which aims at eliminating both poverty and hunger through achievement of food security and improved nutrition (United Nations, 2014). This study will therefore inform policy makers and several development partners to design strategies that can be supported to enable smallholder farmers' access necessary resources for agricultural intensification.

2. Methodology

2.1 Study area and sampling design

This study was based on data collected from Makueni Sub-county and Nyando Sub-county in Kenya by ILRI/CCAFS in the months of October to December, 2016. These sites were selected for research program by Climate Change, Agriculture and Food Security (CCAFS) as they were considered as hotspots of climate change that is the two selected sites were rapidly developing dry areas according to CCAFS climate change parameters. The two sites are semi-arid. A 10 km by 10 km research grid from both sites which were previously selected in 2012 were resampled (Rufino et al., 2013). 16 villages from each site were picked and 10 respondents from every village were sampled through systematic random sampling and replacement was done on the same resulting to a total of 320 households.

2.2 Analytical Framework

Principal Component Analysis (PCA) was used to group the agricultural intensification practices into clusters called principal components. These uncorrelated components accounts for the total original variance. The very first Principal components to be chosen had the greatest variance with the high percentage of explained variance, which is an index of goodness of fit; the remaining components with low percentages of explained variance are dropped (Cappellari *et al*., 2003). The grouped model is represented as shown below:

$$Y_1 = \theta_{11}x_{12} + \theta_{12}x_2 + \dots\dots\dots + \theta_{1n}x_n$$

$$Y_2 = \theta_{21}x_{21} + \theta_{22}x_2 + \dots\dots\dots + \theta_{2n}x_n \quad (1)$$

. . .

$$Y_j = \theta_{j1}x_{j1} + \theta_{j2}x_2 + \dots\dots\dots + \theta_{jn}x_n \quad (2)$$

Where Y_1 ,…………………, Y_j = principal components which are uncorrelated

$\theta_1 - \theta_n =$ Correlation coefficient

x_1 ,……, x_j , = socioeconomic factors affecting agricultural intensification practices

3. Results and discussions

Descriptive statistics

The descriptive statistics of smallholder farmers' socio-economic, farm and institutional characteristics as well as agricultural intensification practices are presented in Table 1 and 2 below.

Table 1. Mean and t-values of farm and farmer characteristics for continuous variables.

Variables	Wote		Nyando		Combined		
	Mean	Sd	Mean	Sd	Mean	Sd	t-value
Age of the household head	56.05	16.086	54.696	14.820	55.371	15.455	0.7846
Education of the household head	2.063	1.068	1.842	1.044	1.953	1.060	1.8636*
Household size	5.687	3.151	5.919	2.487	5.804	2.835	-0.7317
Land size	8.700	9.044	6.221	8.579	7.457	8.887	2.5193**
Distance to extension services	4.846	2.333	7.419	4.200	6.136	3.631	-6.7804***
Number of extension services	.794	1.166	.373	1.089	.583	1.146	3.3443***
Distance to the market	2.732	2.470	3.648	3.268	3.191	2.929	-2.8315***
Number of trainings	.875	1.263	.475	1.369	.675	1.330	2.7170***
Group participation	6.325	2.598	5.181	2.740	5.753	2.727	3.8316***
Group trust	7.356	2.506	6.425	2.962	6.891	2.779	3.0359***

Notes: ***, **, *, indicates significance level at 1%, 5% and 10% respectively

Table 2: Farmers usage of agricultural intensification practices (Number of farmers)

Variables	Site	No. farmers using practice	No. farmers not using practice	Chi Square
Fertilizer	Wote	10	150	80.7768 ***
	Nyando	83	77	
Manure	Wote	124	36	4.1278**
	Nyando	138	22	
Compost	Wote	41	119	40.8631***
	Nyando	2	158	
Pesticides	Wote	98	62	34.1414***
	Nyando	46	114	
Hybrid seeds	Wote	110	50	15.2226***
	Nyando	139	21	
Ash	Wote	1	159	.3365
	Nyando	2	158	
Irrigation	Wote	21	139	10.2130***
	Nyando	44	116	
Intercrop	Wote	154	6	13.8889***
	Nyando	134	26	
Legume fertilizer	Wote	160	0	8.2051***
	Nyando	152	8	
Vaccination	Wote	74	86	7.8644***
	Nyando	86	74	
Deworming	Wote	143	17	0.0321
	Nyando	142	18	
Antibiotics	Wote	107	53	0.4945
	Nyando	101	59	
Traditional	Wote	33	127	0.8696
	Nyando	40	120	
Spray/dip	Wote	84	76	1.5341
	Nyando	95	65	
Improved breed	Wote	11	149	53.1638***
	Nyando	64	93	
Agroforestry	Wote	75	85	25.9611***
	Nyando	32	128	

The results in Table 1 revealed that size of land owned by smallholder households in Wote and Nyando Sub-counties were significantly different at 5% level. On average, household land size in Wote Sub-County and Nyando

Sub-County were 8.7 acres and 6.22 acres respectively. Land is a sign of wealth in African society, a large land size could mean more farm output this can only be possible if the farmland is productive leading to higher income which can be used to meet both labour and input costs for intensification practices.

In regard to the distance from extension services, farmers from Wote Sub-County were on average closer to extension service providers (4.8 kilometers) than farmers in Nyando Sub-County who were on average 7.4 kilometers away. This was significantly different at 1% level. Distance from extension services may affect the level of smallholder farmers' opportunities of engaging in agricultural intensification practices. This can be attributed to the fact that some farmers require frequent advice and believe in agricultural extension officers who are more knowledgeable because this is their area of specialization. Number of extension services in both Sub-Counties were low, smallholder farmers in Wote Sub-County had 0.79 mean number of extension services compared to 0.37 mean number of extension services for smallholder farmers in Nyando Sub-County and this was statistically significance at 1% level.

Distance to the nearest market was significantly different at 1% level for all smallholder farmers in Wote and Nyando Sub-Counties. Distance to the market is an important variable as it enables farmers to access farm inputs, information, and it also affects the transportation cost of both inputs purchased and output products to be sold. The results indicate that farmers in Wote and Nyando Sub-Counties on average travel to the market at a distance of 2.7 kilometers and 3.6 kilometers respectively.

Training improves the ability of farmers to embrace agricultural intensification practices. The result revealed that number of trainings in Wote and Nyando Sub-Counties were statistically different at 1% significance levels. Farmers in Wote received more training than those in Nyando as shown by average level of 0.875 and 0.475 respectively.

Trust among members of the group was measured in a scale ranked from 0 to 10. Existence of trust among group members would make them share knowledge, experiences and challenges freely and also make them exchange ideas, advice one another and this helps in reducing information asymmetry leading to uptake of agricultural intensification practices hence increased farm output. Trust level was significantly different at 1% level. Farmers in Wote Sub-County had the highest level of trust with an average value of 7 compared to Nyando Sub-County which had a mean of 6. Farmers with a higher trust in a group will be motivated to participate effectively in order to reap more from the group. Group participation was also found to be significant at 1% level.

Table 2 shows agricultural intensification practices which were applied by farmers in both Wote Sub-County and Nyando Sub-County respectively. In table 2, the results show that only 6% of farmers in Wote Sub-County used fertilizer compared to 51% of farmers in Nyando Sub-County. There was a significant difference in fertilizer usage by smallholder farmers in the two sub-counties at 1% level of significance.

Manure was highly used by farmers in both Wote and Nyando Sub-Counties. There was 5% level of significant difference in manure usage in both Wote and Nyando Sub-Counties at 77% and 85% respectively. Compost was minimally used by farmers in Nyando in comparison to Wote at a rate of 1% to 25%, this might be due to the fact that Wote farmers received high number of extension services than Nyando.

Agroforestry, intercrop and pesticides were highly applied in Wote Sub-county than in Nyando Sub-county by smallholder farmers at 1% level of significance. Improved seed variety, vaccination, irrigation and improved livestock breeds were both applied by farmers in Wote and Nyando Sub-Counties. However, more farmers in Nyando Sub-county were engaged in these intensification practices than farmers in Wote Sub-county at one percent significance level.

Level of usage of agricultural intensification practiced by smallholder farmers

Agricultural intensification practices are grouped using the Principle Component Analysis which only select datasets explaining higher percentage of total variability. The last section of this objective clearly indicates similarities and differences in the level of usage of agricultural intensification practices among smallholder farmers in Nyando Sub-County and Makueni Sub-County.

From the result smallholder farmers in Makueni and Nyando Sub-Counties used 16 agricultural intensification practices in their farming systems. Some of these intensification practices were correlated with one another so Principal Component Analysis (PCA) was used to group these practices in order to reduce the data set as well as to make them orthogonal. Principal Component Analysis helps in reducing data dimensionality without loss of much information. This study has used Kaiser Criterion in choosing number of principle components. Principle components with Eigenvalues greater than one are taken because they explain greater variation of the dataset. The rest of the components were dropped as they explained less and less variation of the original variables. Table 3 shows principal components (PCs) and proportion of eigenvalues for each component.

Table 3. Eigenvalue proportion for each principal component

Component	Eigenvalue	Proportion (%)	Cumulative (%)
Comp1	**2.9067**	18.00	18.00
Comp2	**2.0981**	12.99	30.99
Comp3	**1.5469**	9.58	40.57
Comp4	**1.3454**	8.33	48.90
Comp5	**1.1919**	7.38	56.28
Comp6	0.9917	6.14	62.42
Comp7	0.9122	5.65	68.07
Comp8	0.8341	5.16	73.23
Comp9	0.8190	5.07	78.30
Comp10	0.6921	4.29	82.59
Comp11	0.6576	4.07	86.66
Comp12	0.6031	3.73	90.39
Comp13	0.4567	2.83	93.22
Comp14	0.4365	2.70	95.92
Comp15	0.3504	2.17	98.09
Comp16	0.3076	1.91	100

From table 3 above, the reduced dataset of 5 principal components explains 55.62% of the total variability meaning the PCA results explain the data well. The very first component explains 18.17% variance. The second principal component explains 13.11% of the variation. Principal component 3 explains 9.67% variation, while principal components 4 and 5 explain 7.78% and 6.89% of the total variations respectively. The remaining components continue to explain less and less variation in the data hence dropped.

Table 4. Loadings of the five components for agricultural intensification practices

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
Fertilisers	0.1791	**-0.4600**	0.0497	0.1676	0.0089	0.4238
Manure	**0.4030**	0.0455	-0.2424	0.1008	-0.2430	0.3550
Compost	-0.2178	0.1294	0.4145	**-0.4574**	0.1863	0.2624
Pesticides	0.2620	0.2335	**0.2746**	-0.0875	0.1755	0.5260
Hybrid_Seeds	0.1309	-0.2488	0.3844	0.1280	**-0.3989**	0.3960
Ash	-0.0146	-0.0032	0.0680	0.4004	**0.5495**	0.4598
irrigation	0.1522	0.0222	**0.3340**	0.2337	0.2178	0.6387
intercrop	-0.0149	**0.4950**	0.0268	0.3032	-0.2609	0.2947
agroforestry	0.0772	0.1988	**0.4652**	-0.0595	0.0080	0.5606
legume_fert	-0.0065	**0.3743**	0.0738	0.3210	-0.3174	0.4581
impr_breed	0.2468	**-0.4044**	0.1714	0.1438	-0.0091	0.4086
Vaccinations	0.2752	-0.0402	**0.2818**	-0.0919	-0.2268	0.5863
Deworming	0.2947	0.0183	-0.0080	**-0.4386**	-0.1053	0.4950
Antibiotics	**0.4506**	0.1728	-0.1417	-0.1886	0.1222	0.2555
Traditional	0.2592	0.1288	0.0784	0.2218	**0.2786**	0.6137
Spraydip	**0.3860**	0.1269	-0.2646	-0.0935	0.2070	0.3668

Table 4 shows loading of the five principal components given the level of agricultural intensification practices and their coefficients of linear combinations called loadings. The components where each practices falls are in bold.

Table 5. Combinations of agricultural intensification practices

Group	Percentage of users	Components
Livestock treatments and its product for soil nutrients improvement	86.25	Manure Antibiotics Spraying/dipping
Technology oriented practices	99.38	Fertilizer Intercrop Legume (intercrop/rotation) Improved breeds
Farm risk reduction practices	78.75	Pesticides Irrigation Agroforestry Vaccination
Routine farm practices	90.00	Compost Deworming
Improved seed varieties and traditional farm techniques	82.81	Hybrid seeds Ash Traditional

Table 5 shows the composition of each component from the greatest weight to the lowest. The first principal component was livestock treatments and its product for soil nutrient improvement used by 86.25% of farmers and was related to use of manure, antibiotics and spraying/dipping. The second principal component was technology oriented practices applied by 99.38% of all smallholder farmers and was associated with fertilizer application, intercropping, improved breeds and use of legume as an intercrop or rotation. The third principal component which was farm risk reduction practices comprised of pesticides application, irrigation, agroforestry and vaccination and practiced by 78.75% of farmers, while principal component four was routine farm practices applied by 90% of farmers and comprised of compost and deworming. Finally, the fifth principal component included improved seed varieties and traditional farm techniques practiced by 82.81% of farmers who used hybrid seeds, ash in farms and traditional methods of livestock treatment.

Table 6. Farmers' usage of group of agricultural intensification practices (%)

Variables	Site	Using practice	Not using practice	Chi Square
Treatment	Wote	81.25	18.75	6.7457***
	Nyando	91.25	8.75	
Technology	Wote	100	0	2.0126
	Nyando	98.75	1.25	
Risk	Wote	82.5	17.5	2.6891
	Nyando	75	25	
Routine	Wote	91.25	8.75	0.5556
	Nyando	88.75	11.25	
Seed and Traditional	Wote	75	25	13.7221***
	Nyando	90.63	9.37	

***Represent 1% level of significance

The results in Table 6 above shows that both farmers in Makueni and Nyando Sub-county use high percentage of component one but more farmers in Nyando practiced component 1 than those in Wote. This was attributed by the fact that farmers in Nyando use more manure and more likelihood of Acaricide (spraying and dipping) use as shown in table 2. Manure was highly used by farmers in both Wote and Nyando Sub-Counties. There was 10% level of significant difference in manure usage in both Wote and Nyando Sub-Counties at 78% and 86% respectively. For component 2 there was no significant difference on farmers who used these practices as almost all farmers from Wote and Nyando used it. There was also no significant difference on smallholder farmers in Wote and Nyando who used component 3 and 4.

The use of component 5 has 1% level of significant difference between smallholder farmers in the two Sub-Counties. Farmers who were engaged in Seed and traditional practices between Wote Sub-County and Nyando Sub-County were statistically different. This difference might have been caused by use of hybrid seeds which was significant at 1% significant level between the two sub-counties as shown in table 2 where 69% of farmers in Wote adopted the use of hybrid seeds while 87% of smallholder farmers in Nyando used hybrid seeds.

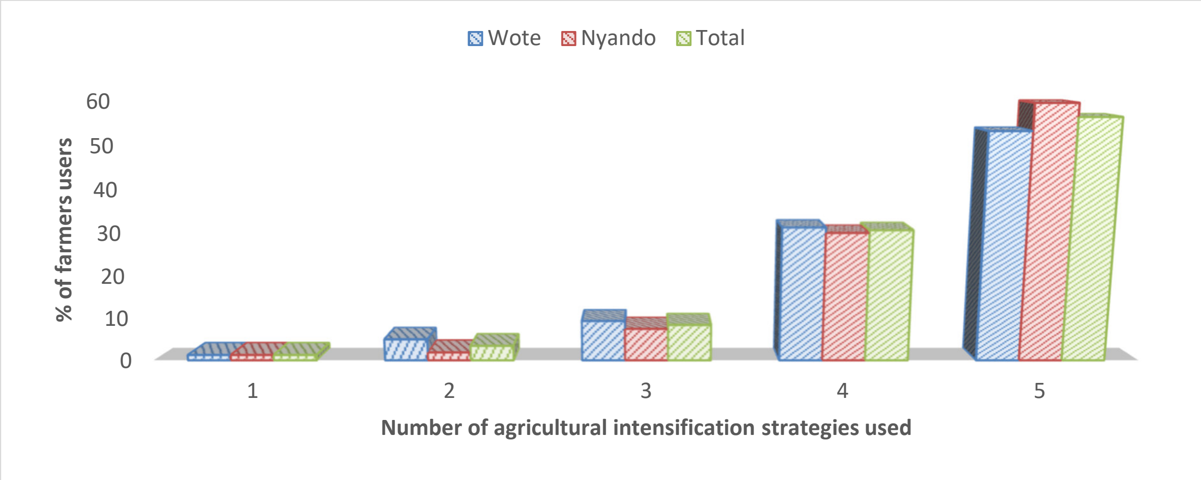

Figure 1. Farmers level of agricultural intensification strategies used

The intensity of agricultural intensification practice was measured by the number of agricultural intensification components (strategies) generated by the Principal Component Analysis. The results in figure 1 above indicated that the number of components of users was ranging from one to five. That is from low users of strategy 1, partial users of 2, 3 and 4 to full users of 5. The result revealed that 56% of farmers used 5 sets of strategies while 31%, 8%, 3% and 1% of farmers' used 4, 3, 2 and 1 levels of strategies respectively.

Figure 1 above further revealed that 53% of farmers in Wote Sub-County used all 5 groups of intensification practices compared to 59% of farmers in Nyando Sub-County. In each of these counties 1% of farmers used only 1 component of intensification practices this was due to the fact that group 2 level of intensification was almost practiced by every farmer who might have adopted zero level of intensification. For farmers who practiced two groups of intensification, Wote farmers had the highest level of 5% than their Nyando counterparts with the level of 2%. Three levels of agricultural intensification practices were practiced by 9% of farmers in Wote Sub-County and 8% of farmers in Nyando respectively. 31% and 30% of rural smallholder farmers in Wote and Nyando Sub-Counties used 4 levels of agricultural intensification practices.

4. Conclusion and Policy Recommendations

This study identified and grouped related farm practices using Principal Component Analysis. Farmers in both sub-counties use at least one level of agricultural intensification practice. Since farmers from these sub-counties are poor and majorly rely on rain-fed agriculture yet they face adverse climatic conditions, they should be empowered to adopt multiple agricultural intensification practices. One way of achieving this is through the government together with other development agencies creating irrigation infrastructure in these regions which will lead to constant water supply hence increased agricultural productivity.

Authors' note

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