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Effects of Regenerative Agriculture Technologies on the Productivity of Cowpea in the Drylands of Embu County, Kenya

Hezron Mogaka

University of Embu, P.O.Box 112, Nairobi, Kenya

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ABSTRACT

Cowpea *(Vigna unguiculata)* is an important indigenous multi-purpose crop grown in arid and semiarid areas of Sub-Saharan Africa (SSA). The cowpea has nutritional and economic value, especially for smallholder farmers in dry lands. However, poor farming practices have declined cowpea productivity over the years. Low soil nutrient replenishment exacerbates the situation, leading to low soil fertility. Uptake of regenerative agriculture (RA) technologies is critical to building more resilient ecosystems that improve soil fertility and agricultural productivity while mitigating climate change effects. This study was carried out to evaluate the impact of the uptake of RA technologies on the productivity of cowpea in the dry lands of Embu County, Kenya. A survey involving 400 farming households was conducted using a semi-structured questionnaire. Descriptive statistics and a stochastic log-linearized Cobb-Douglas production function were used for the data analysis. The study results showed that RA technologies commonly used by farming households were: cereal-legume intercrop, mulching, minimum tillage, crop rotations, pasture cropping, organic agriculture, and compost manure. The findings also revealed that inputs, farm size, labour cost, and used manure amount positively influenced cowpea productivity. The results also showed that cereal-legume intercrop, crop rotations, pasture cropping, and organic agriculture significantly influenced cowpea productivity, while minimum tillage showed a negative relationship. Therefore, the current study's results recommend that the uptake of RA technologies should be scaled to scale up cowpea productivity in dry lands. The study contributes to determining appropriate technologies for cowpea production in arid and semiarid areas. These results will help the government, policymakers, and other inventors to make the right decisions while disseminating or introducing innovations in dry areas.

* Corresponding author

E-mail: hezronmogaka@gmail.com (Hezron Mogaka)

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1 Introduction

Cowpea *(Vigna unguiculata)* belongs to the Family of Fabacea. It is one of the most important annual legume crops in the world. The crop is ranked the second most important legume crop in Sub-Saharan Africa and third in Kenya (Gupta et al. 2019; Njonjo et al. 2019). It's a multi-purpose indigenous crop grown in arid and semiarid areas (Owade et al. 2020a) whose grains and leaves are utilized for human consumption and as livestock feeds, respectively (Owade et al. 2020a). Cowpea leaves contain many essential nutrients, such as vitamins and minerals, that have the potential to improve household nutritional status and food security (Owade et al. 2020b). Most households in dry lands depend on cowpea for food, income, soil management, and also as a source of animal feeds (Gewa et al. 2021).

Cowpea is a drought-tolerant crop that performed well in SSA, especially in dry lands where water stress and low soil fertility are evident, unlike other legumes. In Kenya, 85% of cowpea production areas lie in the Eastern region, characterized by arid and semiarid conditions (Njonjo et al. 2019). The crop is commonly grown in mixed farming systems dominated by sorghum and millet intercropping (Nelson et al. 2021). This crop suits the farming system due to its shade tolerance and early maturity characteristics (Saidaiah et al. 2021). The crop also helps in ecosystem management by improving soil fertility through nitrogen fixation. It gives an alternative to using inorganic fertilizers, especially to resource-constrained farmers in dry areas (Nyaga and Njeru 2020). Despite the various economic importance and nutritional benefits, the crop has been neglected and has a limited value chain (Mfeka et al. 2019).

The productivity of cowpea is reportedly declining globally, with farmers realizing about 260 kg/ha despite increasing land under cowpea production (Njonjo et al. 2019). In East Africa, Kenya holds the most prominent land under cowpea production (FAOSTAT 2019), albeit a low productivity trend attributed to extreme weather conditions and poor application of recommended agronomic practices (Kephe et al. 2021). According to Elrick et al. (2022), regenerative agriculture (RA) technologies offer solutions to these problems and opportunities to scale up productivity, profitability, and household food security while ensuring environmental sustainability.

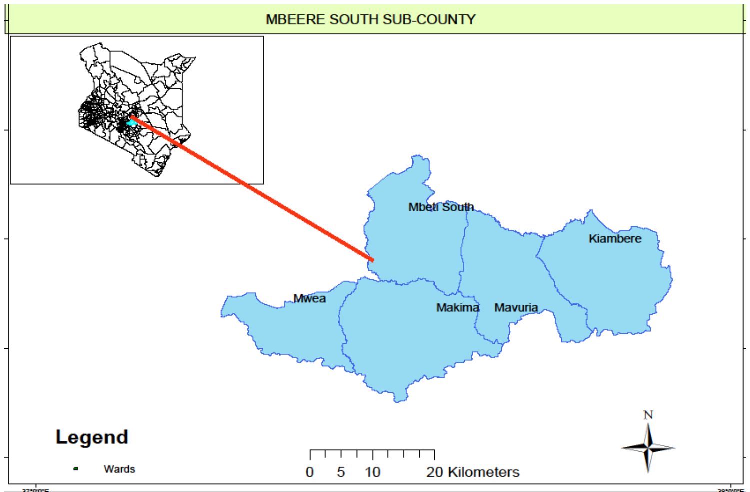
The regenerative agriculture approach uses soil conservation at the entry point to regenerate and contribute to numerous provisions, regulations, and ecosystem-supporting services to improve environmental, social, and economic dimensions (Schreefel et al. 2020). This approach is anchored to the four principles, i.e., integrated pest management practices, advances in plant breeding, soil fertility practices, and integrated crop-animal systems (Schulte et al. 2022). RA emphasizes not or low using synthetic fertilizers or pesticides. It is suggested as an alternate food production method with less adverse environmental and social effects or none at all. It aims to improve soil health and restore highly degraded soil fertility and land productivity through external inputs, utilization of on-farm inputs, integration of crops with livestock, and reducing or eliminating of tillage (Newton et al. 2020). Practices that underpin RA include intercropping cereal crops with legumes, mulching, cover cropping, agroforestry, controlled traffic, pasture cropping, minimum tillage, crop rotations, organic agriculture, and use of compost manure (Lal 2020). These innovations have been suggested to offer opportunities to farmers, especially in dry lands. RA technologies can improve ecosystems by regenerating degraded soils, scaling productivity, increasing household incomes, and boosting food security. However, no RA practice fits all the practices in different soils and agroecological zones (Lal 2020). Thus farmers should adopt more than one technology simultaneously, allowing the use of closely related practices.

The process of adopting innovations remains an important aspect in most developing countries. In literature, innovation and technologies have been used interchangeably (Worku 2019). The uptake of agricultural innovations is influenced by the farmer's perceptions, personality, and social characteristics (Rosario et al. 2022). Scholars have used three models to describe the adoption process, i.e., innovation-diffusion, economic constraint, and perception of adoption (Dissanayake et al. 2022). The diffusion of innovation model considers if the technology is technically and culturally relevant to users. The economic model considers the affordability of the technology to local users, while the adoption model's perception considers the various aspects of the technology that influence farmers' adoption behavior (Ikehi et al. 2022). Demonstrating that, despite the innovator's best efforts to develop innovations that can have a favorable impact on production, farmers will nevertheless view the technologies differently (Dissanayake et al. 2022). Thus, researchers need to collaborate with farmers to discover issues that may hinder the uptake of the innovations they come up with (Ikehi et al. 2022). This can be achieved through farmer training and creating awareness in every stage of technology development. Based on these theoretical models, regenerative agriculture (RA) technologies were disseminated to farmers in the study area. However, the effects of various technologies on cowpea productivity haven't been documented. Therefore, this study is designed to evaluate the impact of the uptake of regenerative agriculture (RA) technologies on cowpea productivity in the dry lands of Embu County at the household level.

2 Materials and methods

2.1 Study area

The study was conducted in Mbeere South Sub County, Embu County, Kenya. The area is a Lower Midland (LM4)



agroecological zone with hot and dry conditions suitable for drought-tolerant crops and livestock keeping. Pigeon peas, sorghum, millet, green grams, and cowpeas are the crops commonly grown in the area (Kiboi et al. 2019; Muthee et al. 2019). The Sub County is located on the South-Eastern slopes of Mt Kenya at an altitude of 700M to 900M above sea level. The rainfall is bi-modal, with long rains from mid-March to June and short rains from mid-October to February, with annual rainfall ranging between 700mm to 900mm. The mean annual temperatures range from 20.7^{0}C to 22.5^{0}C with a latitude of 0°46′S and a longitude of 37°39′E (Wafula et al. 2022). The sub-county covers approximately 1,312 km^2 with a population of about 163,476 (KNBS 2019). Cowpea productivity has declined over the years following poor farming methods that lead to nutrient mining. This has led to low agricultural productivity posing a threat to household food security as most of the households in the area rely on rain-fed small-scale agriculture.

2.2 Experimental design

The research design for the study was a cross-sectional survey. The study targeted approximately 27,274 rural-based farming households in Mbeere South Sub County (KNBS 2019). The following Cochran formula has been used to estimate the sample size:

$$n_0 = n_0 = \frac{Z^2 PQ}{d^2} = \frac{(1.96)^2(0.5)(0.5)}{(0.049)^2} = 400 \quad (1)$$

Where n_0 = required sample size, Z = (1.96) t value from normal table, p = (0.5) probability of success, q = (0.5) probability of failure and d= (0.049) desired level of precision

The respondents were chosen using a purposeful multistage stratified sampling method with probability proportionate to size. Mbeere South Sub-County was purposively selected based on its semiarid characteristics, its potential in cereal and pulse production, and interventions on RA. In the first stage, all five wards in the selected Sub-County were selected. The second stage involved choosing one sub-location randomly from each ward, and the final step involved choosing one village randomly from each sub-location. Using a sample frame obtained from the ward agricultural offices, a probability proportionate to size sampling approach was utilized to determine the total number of families to be questioned in each village.

2.3 Data collection and statistical analysis

A semi-structured questionnaire was used to collect data from 400 respondents. The questionnaire had three sections, i.e., demographic characteristics of the respondents, information on cowpea production, and information on RA. Using the Open Data Kit (ODK) software, the questionnaire was programmed into an electronic format and pre-tested for validity and reliability, and all the reported mistakes were fixed before it was distributed to the respondents. Trained enumerators did the daily data uploading and administration of the surveys.

Data collected were analyzed using Statistical Package for Social Sciences (SPSS version 27) computer program. Basic descriptive statistics, such as frequencies and percentages, were performed. The effects of RA technologies on cowpeas productivity were evaluated, and a stochastic log-linearized Cobb-Douglas production function was used (Isaboke and Musyoka 2022). The production function is expressed as;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n + \alpha_1 Z_1 + \cdots + \alpha_n Z_n + \epsilon \quad (2)$$

Considering the natural logarithm, the production function is expressed as;

$$\ln Y = \ln\beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 X_3 + \cdots + \beta_n \ln X_n + \alpha_1 Z_1 + \cdots + \alpha_n Z_n + \epsilon \quad (3)$$

Where Y=Cowpea yield produced in Kilograms, $\beta 0$= intercept, X_1 $to\ Xn$ = inputs used in production, $\beta_1\ to\ \beta n$ = parameter estimates of the explanatory variables, α_1 to α_n= coefficients of RA technologies, $z_1 to zn$= RA technologies, ln= natural logarithm, and ε is the error term.

3 Results

3.1 Socioeconomic characteristics of the households

Table 1 shows the household's socioeconomic characteristics and reports that most household heads were aged between 31-50 years (44.25%) while the youths comprised 24.50% only. Further, most households were headed by males (59.75%), and females directed a few (40.25%). Most (80.75%) of the studied respondents were married, while only 19.25% were unmarried. Results of the study also suggested that most household heads (50.00%) attained only a primary level of education, and only (5.25%) attained post-secondary education. Regarding farming experience, 37.75% of the household heads had farming experience between 10-20 years, and most households (45%) owned 2-5 acres of land. The main occupation for most households (86%) was crop farming. In addition, a few household heads (39.00%) also engaged in the off-farm activity.

3.2 Main Regenerative Agriculture technologies used by farming households

The leading RA technologies commonly used by farming households in the area of study are summarized in Table 2. The results of the study revealed that cereal-legume intercrop (69.75%), mulching (74.50%), minimum tillage (30.50%), use of compost manure (26.50%), pasture cropping (70.00%), crop rotations (93.75) and organic agriculture (77.75%) are the some common RA technologies which have been used by the respondents.

Table 1 Socioeconomic characteristics of the households

Variable	Group	Frequency	Percentage (%)
Age (years)	18-30	98	24.50
	31-50	177	44.25
	More than 50	125	31.25
Gender	Male	239	59.75
	Female	161	40.25
Marital status	Married	323	80.75
	Not married	77	19.25
Education level	None	74	18.50
	Primary	200	50.00
	Secondary	105	26.25
	Post-secondary	21	5.25
Main occupation	Crop farming	344	86.00
	Crop and livestock	30	7.50
	Salaried worker	8	2.00
	Self-employed	18	4.50
Experience in farming (years)	Less than 10	127	31.75
	10-20	151	37.75
	More than 20	122	30.50
Off-farm occupation	Yes	156	39.00
	No	244	1.00
Total land holding (acres)	Less than 2	59	14.75
	2-5	180	45.00
	More than 5	161	40.25

Table 2 Descriptive results for RA technologies commonly used by farming households

Technology	Frequency	Percentage (%)
Cereal legume intercrop	279	69.75
Mulching	298	74.50
Minimum tillage	122	30.50
Use of compost manure	106	26.50
Pasture cropping	280	70.00
Crop rotations	375	93.75
Organic agriculture	311	77.75

3.3 Effects of Regenerative Agriculture technologies on the productivity of cowpeas

The combined effect of RA technologies and inputs on cowpeas productivity was estimated using a stochastic log linearized Cobb-Douglas production function. Multiple regression procedures in SPSS software were used for model development. The results of Cob-Douglas multiple regressions (Table 3) showed that the model gave an R-square value of 0.7625, which implies that the explanatory variables explained 76% of variations in cowpeas productivity in the study area. The F value (100.31) was highly significant at 1 % (0.000). The tolerance value for each variable was computed to test the significance of regression coefficients. The results revealed t-values greater than 0.1 for significant variables suggesting an increased difference between the null hypothesis and the variables. VIF values for all the explanatory variables were below 5, implying that multicollinearity between the variables was not significant.

Four inputs, i.e., cost of seeds, cost of labour, farm size, and quantity of manure, were included in the production function. Farm size was statistically significant at 1% with a factor of 0.706, while the amount of manure used was significant at 5% with a factor of 0.042. These data suggested that increasing land size under cowpea production by 1% would increase cowpea productivity by 70.6%. On the other hand, increasing the quantity of manure used in cowpea production by 1% increases cowpea productivity by 4.2%. The cost of seeds and labour was also not significant. Seven RA technologies were introduced in the production function to estimate their effects on cowpea productivity (Table 3).

Cereal-legume intercrop, minimum tillage, and pasture cropping were significant at 1%, while organic agriculture and crop rotations were positive and significant at 5%. On the other hand, mulching and the use of compost manure were insignificant. The coefficient of cereal-legume intercrop was positive (0.122) and significant at a 1% level (t=3.704, p=0.000), implying that farmers who

Table 3 Log linearized Cobb-Douglas Multiple Regression Results for Effects of Regenerative Agriculture Technologies on cowpeas Productivity

Variables	Parameters	Beta	SE	t-Value	P-Value	VIF
Constant	β_0	1.820	5.217	0.350	0.727	
Inputs						
Lncost of seeds(Ksh)	β_1	-0.029	0.013	-1.12	0.263	1.05
Lncost of labour (Ksh)	β_2	0.011	0.000	0.45	0.654	1.04
Ln farm size	β_3	0.706	1.307	24.00	0.000***	1.37
Ln manure in Kgs	β_4	0.042	0.018	5.210	0.011**	1.09
RA Technologies						
Cereal-legume intercrop	α_1	0.122	2.114	3.70	0.000***	1.70
Crop rotations	α_2	0.038	3.899	1.44	0.028**	1.13
Mulching	α_3	-0.017	1.759	-0.68	0.499	1.05
Minimum tillage	α_4	-0.078	1.705	-2.84	0.005***	1.19
Pasture cropping	α_5	0.164	2.130	4.90	0.000***	1.70
Organic agriculture	α_6	0.058	2.021	2.06	0.040**	1.24
Use of compost	α_7	-0.012	1.886	-0.43	0.669	1.21
R-squared						0.7625
Prob>F						0.000
Mean VIF						1.25

***significant at 1% and **significant at 5%.

intercropped cowpeas with cereals realized 12.2% higher cowpeas yield compared to non-users of this technology. The results further revealed that rotating cowpeas with other crops would affect cowpea productivity positively (0.038) and significantly (0.028), suggesting that increasing land under crop rotations by 1% would increase cowpea yield by 3.8%. Minimum tillage had a negative coefficient (-0.078) and was significant at a 1 % level (t=-2.843, p= (0.005), implying that practicing minimum tillage decreases cowpeas yield by 7.8%. Further, Pasture cropping was positively significant at a 1% level (t=4.995, p=0.000) with a coefficient of 0.164, implying growing cowpeas together with pasture crops would increase cowpeas yield by 16.4%. Further, the results indicated that practicing organic agriculture positively (0.058) and significantly (t=0.058, p=0.040) influenced cowpeas productivity at a 5% level. Suggesting that increased use of organic inputs in cowpeas production by 1% increases yield by 5.8%.

4 Discussion

4.1 Main Regenerative Agriculture technologies commonly used by farming households

The leading RA technologies used by farming households were cereal-legume intercrop, crop rotations, organic agriculture, minimum tillage, mulching, pasture cropping, and compost manure. These findings corroborate with Mpanga et al. (2021), who noted that smallholder farmers commonly adopt these technologies, especially those in dry areas in Kenya, where extreme weather events dominate.

4.2 Effect of the use of Regenerative Agriculture technologies on the productivity of cowpea

Cowpeas productivity was hypothesized to be a function of factor inputs and RA technologies. The combined effect was estimated using a stochastic Log linearized Cobb-Douglas production function. The calculated results revealed that the quantity of manure used positively influenced cowpea productivity. The findings resonate with Islam et al. (2021), who noted that manure application at the recommended rates significantly affected agricultural productivity. Drylands are usually water-stressed, and using organic manure helps increase microbial activity and water retention capacity, leading to increased grain yield. In addition, organic inputs help improve soil quality and reduce the use of chemical fertilizers, which ensures environmental quality to mitigate climate change effects (Kareem et al. 2021).

Farm size has significantly and positively influenced cowpea's productivity. This indicates that farmers with large farms and adopting RA technologies were likely to realize more cowpea yield per unit area than those with smaller farms, which could be associated with more space to practice innovations and increased plant population. These results are similar to those of Moronge and Nyamweya (2019), who noted that farm size influences adoption as large land gives space to experiment and practice innovations, which could lead to increased productivity. According to Shah et al. (2021), farm size and the process of technology uptake have a relationship with agricultural productivity.

Intercropping cereals with legumes in the study area showed a positive and significant association with the production of cowpeas. Intercropping implies that adopters of this technology had a 1.2% higher cowpea yield than non-adopters. According to descriptive data, 71.3% of the respondents (Table 1) used cereal legume intercrop technology. Intercropping has been proven to have many advantages on cropping systems, including ecological balance, more utilization of resources, enhancement of crop productivity, and sustainability in agricultural production (Maitra and Gitari 2020). A study by Weih et al. (2021) on the effects of intercrop components on yield stability showed that cereal legume experiments had higher yield stability than sole crop experiments.

The relationship between crop rotations and cowpea productivity was positive and significant, indicating that rotating cowpeas with other crops, especially nonlegumes, could increase cowpea productivity. Moreover, rotating pulse crops with cereal crops increases economic returns and reduces nitrogen fertilizer use. The study of Liu et al. (2020) on crop rotation of pea and lintel crops with wheat in semiarid areas suggested that crop rotation positively affected crop productivity. This enhancement in crop productivity was associated with the combined effects of nitrogen benefits between a cereal and a pulse and also gave soil water conservation benefits from branched and deep-rooted legumes that allow for water and nutrient uptake during stressful conditions (Zhao et al. 2022). In addition, rotating cereals and pulses help in pest and disease control, improve soil health, and significantly influence grain yield (Darai et al. 2021).

The results also revealed that uptake of minimum tillage reduced yield by 7.8%, suggesting that cowpea farmers who adopted minimum tillage were likely to get lower yield than non-adopters. The findings of Jena (2019) minimum tillage did not positively impact yield improvement on the adopter. The lower yield can be associated with the agroecological conditions of the study area. The impacts of new innovations on agricultural productivity are highly dependent on rainfall, soil types, inorganic inputs used, and socioeconomic drivers such as returns from production (Mwaura et al. 2021). However, the brighter side of minimum tillage is labour saving. According to Jena (2019), there is significant labor saving from minimum tillage, especially for women. Women provide more farm labour than men in most developing countries. Thus, minimum tillage has a labour-saving impact on farming households headed by women.

Pasture cropping also significantly influenced cowpea's productivity, and farmers who planted cowpeas with a pasture crop were more likely to have a 1.6% yield increase than those who did not. Pasture cropping involves planting a cereal or legume crop into a living perennial pasture, and adopters of this innovation gain more profits (Cougnon et al. 2022). Pastures help control pests, diseases, and weeds and serve as livestock feed (Luna et al. 2020). They also help in ecosystem sustainability by reducing nitrate leaching, controlling soil erosion, and improving water infiltration (Martin et al. 2020). As RA attempts to ensure environmental sustainability, cultivating cowpeas alongside pastures will increase agricultural productivity while restoring degraded soils.

Further, the findings show that the uptake of organic agriculture significantly affects cowpeas productivity in the study area, and the use of organic inputs in the production of cowpeas will increase yield by 0.5%. In comparison between organic and conventional agriculture, it was reported that net returns from organic agriculture were higher than those from traditional farming (Durham and Mizik 2021). The higher returns were attributed to fewer financial inputs as organic farming heavily relies on ecosystem service providers such as biological weed and pest control. Earlier empirical evidence suggests that organic farms are more profitable, environmentally friendly, and produce nutritious food with low chemical residues (Soni et al. 2022).

Conclusion

In conclusion, the current study's findings showed that cereal-legume intercrop, pasture cropping, organic agriculture, mulching, and crop rotations were highly adopted, while minimum tillage and use of compost manure had low uptake. Further, this low uptake could be associated with unfavorable weather conditions in the area of study as well as limited knowledge of the benefits that come with the use of these technologies among cowpea farmers. However, minimum tillage had a significant negative association. This information will help the government and other inventors make appropriate decisions while disseminating or introducing innovations to farmers in dry areas. Thus, farmer exposure through knowledge dissemination could increase the adoption of appropriate technologies to increase cowpea productivity and household food security. Further inventors need to find ways to deal with farmer perceptions and economic well-being that come with innovations to encourage the utilization of new opportunities. The findings are vital in implementing programs to improve agricultural productivity and household food situations in Kenya and other similar environmental countries.

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References

Cougnon, M., Durand, J. L., Julier, B., Barre, P., & Litrico, I. (2022). Using perennial plant varieties for use as living mulch for winter cereals: A review. *Agronomy for Sustainable Development*, *42*(6), 1-21.

Darai, R., Sarker, A., Aryal, L., Gaur, P., & Neupane, R. K. (2021). Adoption and Impact of Pulses Research and Development Strategies for Nepal. *Journal of Horticulture and Forestry*, *3*, 104.

Dissanayake, C. A. K., Jayathilake, W., Wickramasuriya, H. V. A., Dissanayake, U., Kopiyawattage, K. P. P., & Wasala, W. M. C. B. (2022). Theories and Models of Technology Adoption in Agricultural Sector. *Human Behavior and Emerging Technologies*, *2022*. https://doi.org/10.1155/2022/9258317

Durham, T. C., & Mizik, T. (2021). Comparative economics of conventional, organic, and alternative agricultural production systems. *Economies*, *9*(2), 64.

Elrick, W., Luke, H., & Stimpson, K. (2022). Exploring opportunities and constraints of a certification scheme for regenerative agricultural practice. *Agroecology and Sustainable Food Systems*, *46*(10), 1527-1549.

FAOSTAT (2019). Food Agriculture and Organization (FAOSTAT). Retrieved from http://www.fao.org/faostat/en/#data/QC

Gewa, C. A., Stabile, B., Thomas, P., Onyango, A. C., & Angano, F. O. (2021). Agricultural Production, Traditional Foods and Household Food Insecurity in Rural Kenya: Practice, Perception and Predictors. *Journal of Hunger & Environmental Nutrition*, 1-24. https://doi.org/10.1080/19320248.2021.1994083.

Gupta, R. K., . P., Arya, M., Kumar, A., & Kumari, P. (2019). Study on Genetic Variability in Cowpea [Vigna unguiculata (L.) Walp]. *Current Journal of Applied Science and Technology*, *2019*, 1–8. https://doi.org/10.9734/cjast/2019/v33i230057

Ikehi, M. E., Ejiofor, T. E., Ifeanyieze, F. O., Nwachukwu, C. U., & Ali, C. C. (2022). Adoption of agricultural innovations by farmers in Enugu State, Nigeria. *International Journal of Agricultural Technology*, *18*(1), 123–140.

Isaboke, H. N., & Musyoka, K. (2022). Analysis of the factors affecting farm-level output of mangoes among small-scale farmers in Mwala Sub-County, Kenya. *International Journal of Agricultural Technology*, *18*(3), 991-1000

Islam, M. R., Jahan, R., Uddin, S., Harine, I. J., et al. (2021). Lime and organic manure amendment enhances crop productivity of wheat–mungbean–t. aman cropping pattern in acidic piedmont soils. *Agronomy*, *11*(8), 1595.

Jena, P. R. (2019). Can minimum tillage enhance productivity? Evidence from smallholder farmers in Kenya. *Journal of Cleaner Production*, *218*, 465–475. https://doi.org/10.1016/j.jclepro.2019.01.278

Kareem, A., Farooqi, Z. U. R., Kalsom, A., Mohy-Ud-Din, W., Hussain, M. M., Raza, M., & Khursheed, M. M. (2021). Organic Farming for Sustainable Soil Use, Management, Food Production and Climate Change Mitigation. In S.A. Bandh (eds) *Sustainable Agriculture* (pp. 39-59). Springer, Cham.

Kenya National Bureau of Statistics. (2019). Kenya population and housing census analytical reports. Nairobi: Government Press.

Kephe, P. N., Ayisi, K. K., & Petja, B. M. (2021). Challenges and opportunities in crop simulation modelling under seasonal and projected climate change scenarios for crop production in South Africa. *Agriculture & Food Security*, *10*(1), 1-24.

Kiboi, M. N., Ngetich, K. F., Fliessbach, A., Muriuki, A., & Mugendi, D. N. (2019). Soil fertility inputs and tillage influence on maize crop performance and soil water content in the Central Highlands of Kenya. *Agricultural Water Management*, *217*, 316–331. https://doi.org/10.1016/j.agwat.2019.03.014

Lal, R. (2020). Regenerative agriculture for food and climate. *Journal of Soil and Water Conservation*, *75*(5), 123A-124A.. https://doi.org/10.2489/jswc.2020.0620A

Liu, K., Bandara, M., Hamel, C., Knight, J. D., & Gan, Y. (2020). Intensifying crop rotations with pulse crops enhances system productivity and soil organic carbon in semiarid environments. *Field Crops Research*, *248*, 107657. https://doi.org/10.1016/j.fcr.2019.107657

Luna, I. M., Fernández-Quintanilla, C., & Dorado, J. (2020). Is pasture cropping a valid weed management tool. *Plants*, *9*(2), 1–13. https://doi.org/10.3390/plants9020135

Maitra, S., & Gitari, H. (2020). Scope for adoption of intercropping system in Organic Agriculture. *Indian Journal of Natural Sciences*, *11*(63), 28624-28631.

Martin, G., Durand, J. L., Duru, M., Gastal, F., et al. (2020). Role of ley pastures in tomorrow's cropping systems. A review. *Agronomy for Sustainable Development*, *40*(3),1-25. https://doi.org/10.1007/s13593-020-00620-9

Mfeka, N., Mulidzi, R. A., & Lewu, F. B. (2019). Growth and yield parameters of three cowpea (*Vigna unguiculata* L. Walp) lines as affected by planting date and zinc application rate. *South African Journal of Science*, *115*(1), 1–8. https://doi.org/10.17159/sajs.2019/4474

Moronge, J., & Nyamweya, J. M. (2019). Some socioeconomic drivers of agroforestry adoption in Temiyotta Location, Nakuru County, Kenya. *Journal of Sustainability, Environment and Peace*, *2*(1), 9-14.

Mpanga, I. K., Schuch, U. K., & Schalau, J. (2021). Adaptation of resilient regenerative agricultural practices by small-scale growers towards sustainable food production in north-central Arizona. *Current Research in Environmental Sustainability*, *3*, 100067.

Muthee, A. I., Gichimu, B. M., & Nthakanio, P. N. (2019). Analysis of Banana production practices and constraints in Embu county, Kenya. *Asian Journal of Agriculture and Rural Development*, *9*(1), 123–132. https://doi.org/10.18488/journal.1005/2019.9.1/1005.1.123.132

Mwaura, G. G., Kiboi, M. N., Bett, E. K., Mugwe, J. N., Muriuki, A., Nicolay, G., & Ngetich, F. K. (2021). Adoption Intensity of Selected Organic-Based Soil Fertility Management Technologies in the Central Highlands of Kenya. *Frontiers in Sustainable Food Systems*, *4*(3), 570190. https://doi.org/10.3389/fsufs.2020.570190

Nelson, W. C., Hoffmann, M. P., Vadez, V., Rötter, R. P., Koch, M., & Whitbread, A. M. (2022). Can intercropping be an adaptation to drought? A model-based analysis for pearl millet–cowpea. *Journal of Agronomy and Crop Science*, *208*(6), 910-927.

Newton, P., Civita, N., Frankel-Goldwater, L., Bartel, K., & Johns, C. (2020). What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes. *Frontiers in Sustainable Food Systems*, *4*(194). https://doi.org/10.3389/fsufs.2020.577723

Njonjo, M. W., Muthomi, J. W., Mwang'Ombe, A. W., & Carozzi, M. (2019). Production Practices, Postharvest Handling, and Quality of Cowpea Seed Used by Farmers in Makueni and Taita Taveta Counties in Kenya. *International Journal of Agronomy*, *14*(8),1-12. https://doi.org/10.1155/2019/1607535

Nyaga, J. W., & Njeru, E. M. (2020). Potential of Native Rhizobia to Improve Cowpea Growth and Production in Semiarid Regions of Kenya. *Frontiers in Agronomy*, *2*, 1–13. https://doi.org/10.3389/fagro.2020.606293

Owade, J. O., Abong', G. O., Okoth, M. W., & Mwang'ombe, A. W. (2020a). Trends and constraints in the production and utilization of cowpea leaves in the arid and semiarid lands of Kenya. *Open Agriculture*, *5*(1), 325–334. https://doi.org/10.1515/opag-2020-0038

Owade, J. O., Abong', G., Okoth, M., & Mwang'ombe, A. W. (2020b). A review of the contribution of cowpea leaves to food and nutrition security in East Africa. *Food Science and Nutrition*, *8*(1), 36–47. https://doi.org/10.1002/fsn3.1337

Rosário, J., Madureira, L., Marques, C., & Silva, R. (2022). Understanding Farmers' Adoption of Sustainable Agriculture Innovations: A Systematic Literature Review. *Agronomy*, *12*(11), 2879.

Saidaiah, P., Rao, P. S., Geetha, A., Kumar, A. K., & Kamala, V. (2021). Assessment of genetic diversity based on principal component analysis in vegetable cowpea [*Vigna unguiculata* (L.) Walp.] germplasm. *Annuals of Phytomedicine*, *10*(1), 208-214.

Schreefel, L., Schulte, R. P. O., de Boer, I. J. M., Schrijver, A. P., & van Zanten, H. H. E. (2020). Regenerative agriculture – the soil is the base. *Global Food Security*, *26*,100404. https://doi.org/10.1016/j.gfs.2020.100404

Schulte, L. A., Dale, B. E., Bozzetto, S., Liebman, M., Souza, G. M., Haddad, N., & Arbuckle, J. G. (2022). Meeting global challenges with regenerative agriculture producing food and energy. *Nature Sustainability*, *5*(5), 384-388.

Shah, K. K., Modi, B., Pandey, H. P., Subedi, A., Aryal, G., Pandey, M., & Shrestha, J. (2021). Diversified crop rotation: an approach for sustainable agriculture production. *Advances in Agriculture*, *2021*(7), 9.

Soni, R., Gupta, R., Agarwal, P., & Mishra, R. (2022). Organic Farming: A Sustainable Agricultural Practice. *Vantage: Journal of Thematic Analysis*, *3*(1), 21-44.

Wafula, J. N., Mugendi, F. N., Nthakanio, P. N., Mosioma, J. O., & Onyari, C. N. (2022). Effects of Variety, Spacing and Nitrogen Application on Chickpea (*Cicer arietinum*) Growth and Yield in Embu County, Kenya. *Journal of Experimental Biology and Agricultural Sciences*,*10*(1) page 32 – 47

Weih, M., Karley, A. J., Newton, A. C., Kiær, L. P., Scherber, C., Rubiales, D., & Tavoletti, S. (2021). Grain yield stability of cereal-legume intercrops is greater than sole crops in more productive conditions. *Agriculture*, *11*(3), 255.

Worku, A. A. (2019). Factors affecting diffusion and adoption of agricultural innovations among farmers in Ethiopia case study of Ormia regional state Westsern Sewa. *International Journal of Agricultural Extension*, *7*(2), 137–147. https://doi.org/10.33687/ijae.007.02.2864

Zhao, J., Chen, J., Beillouin, D., Lambers, H., et al. (2022). Global systematic review with meta-analysis reveals yield advantage of legume-based rotations and its drivers. *Nature Communications*, *13*(1), 1-9.