Harnessing farmers', researchers' and other stakeholders' knowledge and experiences to create shared value from On-Farm Experimentation: Lessons from Kenya

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Abstract
Achieving greater sustainability in farm productivity is a major challenge facing smallholder farmers in Kenya. A study was carried out in Kenya to assess the value of On-Farm Experimentation (OFE) to tailor soil fertility and nutrient management technologies to local conditions. Ten OFE maize trials were established across Kenya during the short rains 2021-2022. In each site two treatments, an optimized package of technologies (OT) was compared against common farmer practices package (FP). FP harnessed local knowledge and experiences from farmers and extension while initial OT relied mainly on researcher knowledge and experience. The OFE sites acted as learning sites where farmers could engage and learn both formally through farmer training and field days but also informally through individual exchange. At maturity, the trials were harvested, and maize grain yield determined to compare the two treatments. Overall, the OT yielded more than FP, but the comparisons between farmers and regions varied substantially. Postharvest dialogues were organized with farmers and other value chain actors to share in-season learning experiences and identify the value created for them. Farmers gained higher yield, reduced production costs and increased profits from their enterprises. The researchers had an opportunity to learn from farmers, understand the complexity of local context and develop technological packages that were adapted to the real farming local conditions. This study demonstrates that OFE is an important platform that can accelerate change in Kenyan agricultural landscapes and benefit all parties.

Keywords
On-farm experimentation, participatory approaches, shared values, smallholders

1. Introduction

Agriculture is an important sector for economic growth and development as well as job creation in Africa. It employs about 70% of the workforce, supports the livelihoods of 90% of the rural population, and accounts for about a quarter of the gross domestic product of the continent (OECD, 2016; World Bank, 2016). In Sub-Saharan Africa, agriculture and food security is largely dependent on approximately 33 million smallholder farmers who farm on less than a hectare of land. These smallholder farmers are increasingly confronted by a myriad of biophysical and socio-economic constraints that result in declining yields. Although the average cereal yields in the region rose from about 1.2 t ha^{-1} in 2000 to over 1.7 t ha^{-1} in 2022, they remain very low compared to those in other regions like South East Asia and South America at 4.8 and 5.7 t ha^{-1}, respectively (Vorley et al., 2012).

Smallholder farmers in Kenya, like the rest of the region, face the formidable challenge of sustaining farm productivity in the wake of numerous biophysical and socio-economic challenges. These include low soil fertility, climate change, increasing population and the resultant pressure on land resources, rising costs of inputs such as seeds and fertilizers, limited access to capital, labour, and inefficient output markets (Adolwa et al., 2023; Agyei-Holmes et al., 2020; Ariga et al., n.d.; Gicheru, 2012). Additionally, the farming systems are highly diverse and complex. Many characteristics such as land holding and access, soil fertility, rainfall and temperature regimes, cropping, livestock assets, off-farm activities, labour and cash availability, socio-cultural traits, farm management intensities and livelihood orientations are highly (Adolwa et al., 2023; Giller et al., 2011; Mutegi et al., 2024; Muthamia et al., 2011; S. Njoroge et al., 2019; Tittonell et al., 2005, 2010). Consequently, one-size-fits-all production intensification recommendations are not tenable in these environments because they do not account for the diversity of smallholder socio-ecological and economic contexts, and their goals and interests (Farrow et al., 2019; Sinclair & Coe, 2019; Tittonell et al., 2010; Tittonell, 2014a). Therefore, there is a need to adapt farmer-centric and participatory processes to characterize and understand the ecological, socio-economic, and cultural context of smallholder farmers and fine-tune the technologies to their contexts. However, it is difficult to design, develop and promote sustainable intensification practices that consider the complexity of individual smallholder farms.

There is increasing interest in on-farm experimentation (OFE) as a process that can enhance farmers' and other stakeholders' involvement in development and fine-tuning agricultural technologies to match farmers' needs. It is in this context that the OFE framework was used in a study in Western and Eastern Kenya highlands to characterize smallholder farms and households, identify farm management gaps and tailor the existing blanket soil and nutrient management recommendations into options that match different smallholder farm typologies. This paper is reporting the OFE process and key lessons from Kenya as part of a wider project (Nutrient-Catalyzed Agricultural Transformation - NUTCAT) that is being implemented by APNI in Cote d'Ivoire, Ghana, Senegal, Kenya, Tanzania, Tunisia, Togo. The wider NUTCAT project has three workstreams; (i) Improving cereal system production using precision nutrient management, (ii) use of remote sensing technology to evaluate grain yield potential and spatial variation in smallholder agriculture, and (iii) farmer engagement and on-farm experimentation. This report will concentrate on the 3rd workstream.

2. Materials and methods

1.1 Study area

The study was conducted in five Counties in Kenya namely Siaya and Kakamega in Western Kenya, and Machakos, Embu and Meru in Eastern Kenya. These are predominantly smallholder maize growing areas with contrasting agroecological and socio-economic conditions (Table 1).

Table 1: Main characteristics of the study sites

County	Region	Agroecological zone	Rainfall (mm)	Soil type	Population*
Siaya	Western	Warm, humid, lower midland	1500 - 1900	Ferralsols	993,183 (393)
Kakamega	Western	Warm, humid, lower midland	1280 - 2200	Humic nitisols	1,867,579 (618)
Machakos	Eastern	Dry, semi-arid lower midland	500 - 800	Luvisols	1,421,932 (235)
Embu	Eastern	Warm, humid, upper midland	1000 - 2000	Humic nitisols	608,599 (216)
Meru	Eastern	Warm, humid, upper midland	300 - 2500	Humic nitisols	1,545,714 (221)

*Population densities in parentheses

The study sites are characterized by bimodally distributed rainfall which falls in two distinct seasons, with a long rain (LR) season from March to June and a short rain (SR) season from September to December. The farming systems are characterized by cultivation of a variety of food and cash crops with maize as the main staple food crop. Livestock keeping is also an integral part of the farming system, with cattle, sheep, goats and chicken as the most predominant (Jaetzold *et al*., 2007). Most of the inhabitants of the study area are smallholder farmers although many households also pursue off-farm activities for income including trade, service jobs, selling labour in other farms or crafts.

2.1 Convening of research team, sensitization and selection of stakeholders

2.1.1 Convening of core research team and choice of pilot sites

A core research team was established at APNI to guide and co-ordinate the implementation of the OFE program. The team was comprised of scientists trained in a wide range of disciplines like soil fertility, agronomy, farming systems, sociology, and agricultural economics. The team has established research scientists with a wealth of experience in field implementation of programs and projects focused on improving soil fertility, nutrient management, and food security among smallholder farmers in Africa. The team selected the general study sites based on their knowledge and experiences of key agricultural activities, agroecological and smallholder farming conditions in Kenya. The decision to include study sites in Western and Eastern Kenya was purposively done to cover a wide range of smallholder farmer conditions. The choice of maize as the test crop was because it is the main staple food crop in Kenya and the main aim of the study was to improve the food security status of smallholder farmers. The convening of the core research team was also to facilitate identification of the first level of collaborating partners for the project.

2.1.2 Sensitization, selection and engagement of OFE stakeholders

The first set of sensitizations started at the national level where policy issues in agriculture are handled. As a result of these engagements, a stakeholders' forum (known as Maize Improvement Team) was established with representatives from the Ministry of Agriculture/County Governments, the African Plant Nutrition Institute (APNI), the University of Nairobi, Kenya Agricultural and Livestock Research Organization (KALRO), OCP-Africa, farmer associations like Cereal Growers Association (CGA) among other key maize sector representatives.

The core research team and representatives from the stakeholders' forum visited the County offices for sensitization meetings with agricultural extension officers in the months of August and September 2021. The objective of these meetings was to sensitize the officers about the project; coverage, objectives, activities, expected outputs and outcomes. It is during the sensitization meetings that the sub-counties and wards where the project would be implemented were selected. The meetings also discussed and came up with a list of stakeholders to be involved at the local level. The key stakeholders identified were farmers, extension system (county, sub-county, and ward level), KALRO scientists, national government administration, NGOs working with farmers, private sector players such as inputs suppliers and other service providers in the agricultural value chain. The meetings cascaded to the sub-county and ward levels. The stakeholders at the local (ward) level identified ten farmers to across the five counties to host the OFE experiments.

2.2 Establishment of on-farm experiments

Ten maize OFE trials were established during 2021 short rains season and have been going on for five cropping seasons. The trials followed a simple and easy-to-understand design where two treatments were compared side by side in two plots of approximately 0.4ha each. The treatments were (i) optimized treatment (OT) - a researcher designed, and researcher managed treatment receiving the right type and amount of nutrients that is required to produce a yield target of 7.5t/ha and (ii) farmer practice (FP) – a treatment whereby the farmer establish and manages maize crop the normal way they would do without interference by the scientific team. This means that whereas the OT was fairly standardized across different farms/sites, FP varied from farmer to farmer.

The initial OT had nutrients applied at the rate of 150 kg/ha N, 50 kg/ha P, 60 kg/ha K, 15 kg/ha S and 0.5 kg/ha Zn. The rates were arrived at based on local recommendations and in consultation with scientists working in the selected regions. In addition to the nutrients, OT also incorporated good agronomic practices such as using the correct types of seeds (hybrid), right planting density, appropriate fertilization practices (e.g., 4 R nutrient stewardship), correct weeding and pest management. The OFE platform had representation from a wide range of disciplines including extension/policy, soil science, agronomy, socioeconomics, fertilizer industry, seed breeding/production, and agribusiness. The team was tasked to meet regularly to establish, evaluate, and update the optimized technological package for maize production intensification in the agro-ecozones of interest.

Trials management involved regular contact with the farmers to exchange knowledge on management practices, monitor farmer learning and management changes and evaluate the treatments performance at different stages. Harvesting of maize from OT and FP was done after the crop reached physiological maturity (approximately 120 days after sowing). In each treatment plot, 9 net plots were demarcated on evenly spaced 3x3 m grids. Harvesting was done in the 9 net plots, both grain and stover were weighed. Grain and stover sub-samples were collected, oven dried, and their dry weights determined. This was used in calculating the total grain and stover dry weights.

2.3 Farmer field days

Farmer field days were held at the OFE sites after the crop had attained physiological maturity. The events brought together farmers from several local communities to exchange ideas, learn about new farming practices and agricultural trends. The field days were organized by the African Plant Nutrition Institute (APNI) in collaboration the other OFE stakeholders. These functions were well attended by farmers and a wide range of stakeholders who had the opportunity of showcasing the different products and services they offer. During the farmer field days, we conducted interviews and focused group discussions with various stakeholders to assess the value they would attach to the OFE process.

2.4 Postharvest dialogues

Two postharvest dialogue meetings were held in 2022 and 2023 at the end of long rain seasons. The meetings brought together the NUTCAT project farmers, select non-NUTCAT farmers and the other stakeholders organized in workshop set up. The meetings provided important avenue for sharing insights to better understand the farming system conditions and share experimental data/results from the previous season. It also provided an opportunity to learn from farmers the kind of management changes they would like to make on their farms based on the learning from the season-long engagements with different stakeholders. In-depth interviews and focused group discussions were conducted with different stakeholders to assess the value of the OFE process.

These were aided by various tools such as yield graphs comparing performance of OT and FP treatments in different farms, remote sensing (satellite) maps showing within-and-between farms variabilities in crop performance and value proposition canvas tool was (Osterwalder et al., 2014).

The first postharvest dialogue meeting was held in August 2022 in Siaya, Western Kenya. The meeting brought together 10 NUTCAT project farmers, 10 non-NUTCAT, 16 researchers, and 15 service providers. The discussions majorly focused on understanding the ecological, social and economic conditions under which farmers have to make various farming decisions, review of the yield data from the OFE experiments in the previous season and the lesson learnt out of engagements by different stakeholders. The second postharvest dialogue was held in September 2023 in Nairobi. The meeting involved 10 NUTCAT project farmers, 5 non-NUTCAT, 16 researchers, and 10 service providers. In addition to reviewing the yield data and satellite maps, focused group discussions and in-depth interviews were held to solicit views on the value of OFE process to the engaged stakeholders. The value proposition canvas tool was applied to four different customer segments i.e., NUTCAT farmers, non-NUTCAT farmers, researchers, and service providers to understand their value propositions. The Value Proposition Canvas has two sides, i.e., customer profile and value map. The tool makes the value propositions for different customer segments more visible and tangible, and thus easier to discuss and manage.

2.5 Data analysis

Yield data from OFE trials was statistically analyzed using R package (R Core Team, 2018). Analysis of variance (ANOVA) was carried out to determine whether there were significant differences in yield between the two treatments. Qualitative data from the OFE engagement processes i.e., focused group discussion, in-depth interviews was analyzed thematically.

3. Results and discussion

3.1 Diversity of farmer management practices

As expected, management practices employed in the farmer practice (FP) treatment varied significantly as individual farmers were left to manage their FP plots without any influence or guidance from the research team. The participating farmers were interviewed individually to provide information on how they managed their FP plots (Table 2).

Table 2: Summary of farmer management practices implemented in the FP treatment

Site Name	Crop establishment	Fertilization	Weeding	Pest control
Kakamega_PK	• Ox-ploughing • Early planting before rain onset • Hybrid seed Haraka 101 • Maize-soybean intercrop, rows 1:1 • Recommended spacing (75cm*25cm)	• Basal DAP 125 kg/ha • Topdress with CAN 75 kg/ha, once, 2 weeks after emergence	• Twice, manual • Striga infestation a major challenge	• Fall Armyworm not controlled
Siaya_PO	• Tractor ploughing • Planting 1 week after rains • Hybrid seed DK 8031 & local variety • Maize-bean intercrop, rows 1:1 • Irregular spacing	• Basal DAP 125 kg/ha • Topdress with CAN 125 kg/ha, once, 3 weeks after emergence	• Once, manual • Striga infestation a major challenge	• Chemical control of Fall Armyworm, once
Embu_DW	• Minimum tillage • Early planting before rain onset • Hybrid seed H513	• Basal DAP 125 kg/ha • Topdress with CAN 125 kg/ha, once, 4	• Twice or thrice, non-selective herbicide,	• Chemical control of Fall

	• Sole cropping • Recommended spacing (75cm*25cm)	weeks after emergence	manual weeding	Armyworm, twice
Meru_SM	• Minimum tillage • Early planting before rain onset • Hybrid seed Duma 43 • Sole cropping • Recommended spacing (75cm*50cm) – 2 seeds per hole	• Basal DAP 125 kg/ha • Farmyard manure 2.5t/ha • Topdress with CAN 125 kg/ha, once, 2 weeks after emergence	• Once, selective herbicide	• Chemical control of Fall Armyworm, once
Machakos_DM	• Ox-ploughing • Early (dry) planting • Hybrid seed Duma 43 • Maize-bean-pigeon peas intercrop • Recommended spacing (75cm*50cm) – 2 seeds per hole	• No basal fertilizer • Topdress with CAN 125 kg/ha, once, 2 weeks after emergence • Supplemental irrigation (furrow method)	• Twice, manual/hand weeding	• Chemical control of Fall Armyworm, twice

Farms and farm management practices among the smallholders varied significantly as individual farmers made independent management decisions (Table 2). This is common in the smallholder farming systems where farmers are faced with the challenge of allocating very limited resources to different farm enterprises. These findings compare well the findings by Vanlauwe et al., 2019 who reported the diversity of smallholders farming systems in sub-Saharan Africa and attributed it to contrasted livelihood strategies, socio-economic situations and the heterogeneous biophysical contexts. Similarly, Berre et al., 2022, in a study on structure of smallholder households in Sudano-Sahelian Burkina Faso distinguished 4 types of farm households and 3 types of farm management. In Kenya, Tittonell et al., 2005, 2010 found that smallholder farming conditions in Western Kenya were highly diverse and heterogenous. Many characteristics such as land holding and access, soil fertility, rainfall and temperature regimes, cropping, livestock assets, off-farm activities, labour and cash availability, socio-cultural traits, farm management intensities and livelihood orientations were highly variable. OFE would therefore play a critical role on unraveling these complexities because the process is farmer-centric and occurs in real farming conditions. The farmers are placed at the center of research and are key in shaping technology recommendations.

3.2 Effects of nutrients and other agronomic practices on maize yield

The average maize grain yield from the different sites (farmers) is shown in table 3. In most cases (highlighted in bold), the optimized treatment (OT) performed better than farmer practice as expected. However, there were cases where FP outperformed the OT in the 2 seasons whose data has been presented.

Table 3: Mean grain yield for different farms during Short Rains 2021 and Long Rains 2022

Site_Farmer	SR 2021			LR 2022		
	OT	FP	Sig (Trt)	OT	FP	Sig (Trt)
Kakamega_PW	**3219**	2321	Ns	**4087**	2720	$P < 0.001$
Kakamega_PK	3118	Blank	Na	**5233**	1768	$P < 0.001$
Siaya_PO	**5441**	2286	$P < 0.001$	**6295**	656	$P < 0.001$
Siaya_AO/SO	Blank	Blank	*Na*	**4269**	3820	*ns*
Embu_KP	**3570**	3084	Ns	Blank	Blank	na
Embu_AN	2731	Blank	Na	153	Blank	na

Embu_DW	**4582**	1950	*P < 0.001*	Blank	Blank	*na*
Meru_SM	5408	5733	Ns	**3158**	1954	*P < 0.001*
Machakos_DM	**3467**	844	*P < 0.001*	**1397**	101	*P < 0.001*
Machakos_GM	1226	Blank	Na	Blank	Blank	na

Notes: Blank cells indicate data was not available; either there was crop failure, farmer harvested prior to the scheduled harvesting, or the trial was discontinued. Where there are p values, it indicates significant differences between treatment means in that farm. ns = the treatment means are not significantly different, while na = not actionable due to lack of data.

As observed from table 3, the variations in yield between OT and FP was expected because whereas OT received the optimum level of management, FP depended on resources from farmers which are often limited. In OT, nutrients were applied at the rate of 150 kg/ha N, 50 kg/ha P, 60 kg/ha K, 15 kg/ha S and 0.5 kg/ha Zn. These are considered sufficient to produce over 6t/ha of maize. Additionally, all the good agronomic practices such as use of hybrid seeds, right planting density, appropriate weeding, pest and disease management were implemented correctly. Many studies in Kenya have shown that use of mineral fertilizers combined with good agronomic practices can increase maize grain yield way beyond the current yields attained by farmers (Kihara et al., 2016; Mugwe et al., 2009; Muthaura et al., 2017; R. Njoroge et al., 2018).

The low yields in FP can mainly be attributed to poor crop management. Many studies from the bulk of maize growing areas of Kenya have reported grain yield of less than 2.5 t/ha where no fertilizers or manure have been used (Mucheru-Muna et al., 2007; Muthaura et al., 2017; R. Njoroge et al., 2018). The levels of maize production results from complex interactions among the availability of water and nutrients, competition of weeds, occurrence of pests and diseases and the actual management practices. At the farm level, usage of low yielding varieties, and poor crop management practices such untimely planting, incorrect plant spacing, wrong method of planting, poor sowing depth, delayed or ineffective weeding, ineffective pests and diseases control, lack of or inappropriate use of fertilizers are common. Such poor crop management practices become reflected in reduced crop growth and yield which invariably make farming to be physically strenuous and economically unrewarding.

A similar yield trend observed in stover data, where in most sites, OT yields were significantly higher than FP as was expected (Table 4).

Table 4: Mean stover yield for different farms during Short Rains 2021 and Long Rains 2022

Site_Farmer	SR 2021			LR 2022		
	OT	FP	Sig (Trt)	OT	FP	Sig (Trt)
Kakamega_PW	10166	4247	Ns	5971	3180	*P < 0.001*
Kakamega_PK	4507	Blank	Na	6907	1371	*P < 0.001*
Siaya_PO	7927	3770	*P < 0.001*	8148	180	*P < 0.001*
Siaya_SO	Blank	Blank	*Na*	5816	4392	*ns*
Embu_KP	5638	6012	Ns	Blank	Blank	na
Embu_AN	4678	Blank	Na	2390	Blank	na
Embu_DW	4749	2407	*P < 0.001*	Blank	Blank	*na*
Meru_SM	6413	3289	*P < 0.001*	7843	3504	*P < 0.001*
Machakos_DM	3830	1610	*P < 0.001*	6489	540	*P < 0.001*
Machakos_GM	3890	Blank	Na	Blank	Blank	na

Notes: Blank cells indicate data was not available; either there was crop failure, farmer harvested prior to the scheduled harvesting, or the trial was discontinued. Where there are p values, it indicates significant differences between treatment means in that farm. ns = the treatment means are not significantly different, while na = not actionable due to lack of data.

3.3 Stakeholders' motivations for participanting in OFE process

Participation of different stakeholders in the OFE process was driven by certain motivations or expectations (Table 5). NUTCAT farmers indicated that when they were approached to participate in the project, some were driven by the need to address production challenges in their farms and gain new knowledge, while others mentioned that they were driven by the need to offer fellow farmers a platform for learning (demonstration farm). Some service providers were driven by the need for data to support their extension work or create new customers for their products and services. This variation was also true for their experiences in the process and their suggestions for future engagement.

Table 5: Insights from focused group discussions and individual interviews on the stakeholders' involvement in OFE *process*

Motivation/Expectations	Experiences	Future suggestions
NUTCAT FARMERS		
• Address production challenges (soil, climate, invasive pests) • Gain new knowledge • Offer opportunities for other farmers to learn • New technologies to increase yields	• Positive and sociable interaction • In-depth and practical training	• Expand value chains • Influence government policies
Non-NUTCAT FARMERS		
• To learn about the project • Curiosity • Public extension service not adequate • Immediate economic gain • New technologies	• Positive and sociable interaction • In-depth and practical training	• Expand the project to include more farmers
SERVICE PROVIDERS (Extension system, NGOs, Input companies)		
• New technologies • Create partnerships • Evidence to support extension • Increase revenue • New customers	• Positive and sociable interaction • Refresher practical training	• Expand value chains and area coverage • Influence government policy
RESEARCHERS		
• Positive collaboration • Understand real farm conditions • To gain new knowledge	• Positive and sociable interaction • In-depth and practical training	• Expand value chains

3.4 Impact and value of OFE process to different stakeholders

In defining OFE stakeholders' profile and value mapping, three different OFE stakeholder segments were identified. These were the farmers, researchers and other service providers such as extension providers, inputs suppliers, farm products off-takers and NGOs. All these segments have important roles/activities (jobs) that they undertake in their routine work (Table 6). For instance, farmers must source for resources like land, capital and labour, undertake the farm operations and market their farm outputs. Equally, extension systems must support farmer through training and capacity building, policy formulation and offer linkages to research as well as markets. Researchers on the other hand must carry out experiments to develop technologies and generate knowledge.

Table 6: Stakeholders profile, their key roles and benefits in OFE process

FARMERS	SERVICE PROVIDERS	RESEARCHERS
STAKEHOLDER ROLES/JOBS		
• Sourcing of resources (land, capital, equipment) • Hire workers • Farm operations (land prep, planting, weeding etc) • Storage & marketing products	• Policy formulation & advocacy • Training & extension services • Research linkages • Market linkages •	• Experimentation & technology development • Knowledge generation • Capacity building • Resource mobilization • Influence government policies
PAINS		
• Limited resources (land, finances, labour) • Poor quality inputs • Pests & diseases outbreaks • Climate related risks (droughts, flooding, hailstones) • Limited mechanization • Inadequate extension services • Storage & marketing challenges	• Inadequate extension facilitation • Limited human capital • Inadequate equipment • Limited training & refresher • Gender inequalities • Stagnation at workplace	• Limited resources & infrastructure • Limited human capacity • Ethical issues • Climate related challenges • Gender Imbalance
GAINS		
• Increased yields • Reduced production cost • Increased access to finances • Improved food security • Improved inputs & outputs market • Improved income & profit • Increased farmer motivation & social cohesion • Improved social status • Better & informed decision-making	• Reduced cost of extension • Improved technology dissemination & adoption • Data driven policy • Improved food, health, nutrition & incomes • More business for private sector • New customers for private sector • New partnerships • Staff motivation	• Improved knowledge of local conditions • More adoptable technologies • Unlocked research support (funding) • Reduced research costs • Improved food security • Enhanced environmental sustainability • Ethical issues easily overcome

Different actors (farmers, researchers and other service providers) must perform their tasks under difficult conditions because of finite resources, risks and vulnerabilities (pains). OFE process therefore brings these different stakeholders together to negotiate, collaborate, and act for the mutual benefit of all. Out of their collaboration, they individually derive different benefits (gains), and this motivates their continued engagement. Farmers may benefit through increased yield, enhanced incomes or reduced production costs out of adopting technologies developed in the OFE process. Extension and policymakers may benefit by formulating data driven policies while researchers by improving their knowledge of local conditions by learning from farmers. This is the kind of mutual relationship that OFE process offers. This highlights the interconnectivity of these players in fulfilling the goals. Lacoste et al., 2022, observed that OFE research is a deliberate process of joint exploration whereby researchers and others engage closely with farming realities to align their private interests and build productive relationships. In other words, the process must recognize the private and intricate interests of all the stakeholders involved.

OFE is a symbiotic relationship, and every participant has private interests and expected gains. For instance, Thompson et al., 2019, found that farmers in Nebraska participated in on-farm research for economic gains. Previous research demonstrates that smallholders conduct many different types of experiments and are driven by a variety of goals. Bentley, 2006 reported that farmer-led experiments were motivated by changes in the environment and the economy, and sort resolve labour and capital constraints. Some studies have reported that farmers participate in on-farm experiments of curiosity or to explore new things (Hockett & Richardson, 2018). Other farmers innovate to produce a positive change in their farming systems, often in response to conditions that are out of their control (e.g., climate change and variability). Just as all farmers have different motivations for experimenting (or not), all farmers have different priorities and goals for their farms (Bentley, 2006; Pannell et al., 2006; Snapp et al., 2019). Cook et al., 2018 observes that it is very important to develop OFE processes around the analysis to generate value, as well as to share it with the stakeholders. He emphasizes that benefits and costs of OFE must be distributed within many different groups (stakeholders) to ensure the continuity of these processes.

4 Summary

In Kenya, tremendous efforts in agronomic research and development have yielded many technologies to address the numerous challenges facing smallholder farmers. However, their adoption is low because the process of experimentation has mostly been top-down. This has led to development of one size fits recommendations that do not consider the highly variable smallholder farmers' biophysical and socio-economic contexts. Farmers are the best interpreters of their needs and capacities within a given context due to the nature of their work, resource endowment and livelihoods, as well as associated risks and uncertainties. Farmers tailor their farm management decision based on their circumstances. This study concludes it is imperative to actively involve farmers in technology development and dissessimation. OFE offers an important platform where agricultural stakeholders can come together to learn, negotiate, collaborate, and act for the mutual benefit of all. Out of their collaboration, they individually derive different benefits (gains), and this motivates their continued engagement.

OFE should therefore be viewed as a deliberate process of joint exploration whereby researchers and others engage closely with farming realities to align their private interests and build functional relationships. The OFE approach offers space for hands-on group learning, enhancing skills for observation and critical analysis and improved decision making by local communities. The success of the OFE process lies in showing how it generates value, as well as sharing it with the stakeholders in a fair manner. The benefits and costs of the process must be distributed within the different stakeholders to ensure the sustainability of these processes. However, OFE is a new concept in the African smallholders' systems and further work is needed tailor it to the local circumstances. A key consideration should be the need to detailed characterization of farms and households the start of the OFE process to enhance inclusivity.

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