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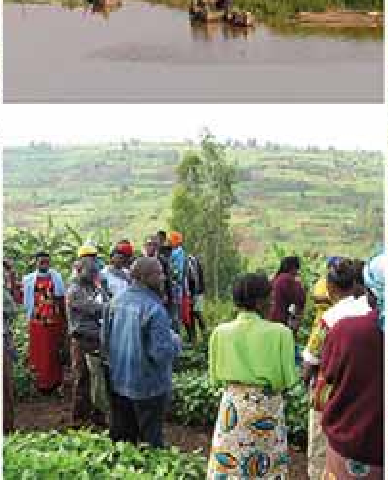
Sustainable Intensification in Smallholder Agriculture

An integrated systems research approach








12 Using local knowledge to understand challenges and opportunities for enhancing agricultural productivity in Western Kenya

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Introduction

Global agricultural systems are relied on to produce enough food to support a rapidly growing population (Mann et al., 2009; Godfray et al., 2010, Bremner, 2012), but many of these systems are currently under threat from land degradation (Deininger et al., 2003; Holden and Shiferaw, 2004), climate change (Schmidhuber and Tubiello, 2007; Lasco et al., 2014; Luedeling et al., 2014), and socio-economic and political forces. Insecurity of tenure, inequalities in access and control of land, poor farming practices, and weak policies and institutions have all been shown to undermine agricultural productivity (Gebremedhin and Swinton, 2003; Musemwa et al., 2015). Furthermore, it has been shown that small-scale agricultural production in many developing countries is dropping, even in 'high potential' areas. This has been attributed to decreasing farm sizes as a direct result of increasing populations and subdivision of land through customary inheritance (Lambin and Meyfroidt, 2011). Agricultural expansion and intensification have resulted in land degradation where sustainable practices have not been implemented (Waithaka et al., 2006).

Despite agriculture being the backbone of the economy in Sub-Saharan Africa (SSA), it is expected that farm sizes will continue to decrease due to customary inheritance and a threshold will be reached, if not already, in terms of farms being able to meet livelihood needs (Conelly and Chaiken, 2000; Waithaka et al., 2006; Masters et al., 2013; Öborn et al., 2015). Studies have shown that food security (in terms of quantity and quality of food) can be seriously jeopardized when farm sizes are too small to meet household needs (Conelly and Chaiken, 2000). According to Waithaka et al. (2006), there appears to be a minimum threshold of 0.4 ha (land area needed being dependent on household size), below which it becomes impossible for households to satisfy their dietary needs from subsistence agriculture alone.

With smallholder agriculture acting as the foundation of food security and an important part of the socio-ecological landscape in SSA (HLPE, 2013), sustainable intensification of these smallholder systems has been suggested as one way of enhancing livelihoods of smallholder farmers. Sustainable intensification has been defined as increasing productivity while maintaining the natural resource base (e.g. soil health) and delivery of ecosystem services, as well as enhancing social and ecological resilience to shocks and stresses including climate change (Vanlauwe et al., 2014). Other definitions emphasize the social dimensions of sustainable production systems, for example, Pretty et al. (2004) add to the above definition by stating that a sustainable production system is also one that makes productive use of human capital in the form of knowledge and capacity to adapt and innovate, and uses social capital to resolve common landscape level problems.

Despite different livelihood strategies being employed for economic improvement and increased agricultural productivity in areas that are facing population pressures and reduced farm sizes, sustainable intensification has largely not been achieved due to the myriad challenges faced by smallholder farmers. There is therefore a need to understand these challenges, identify opportunities, and develop sound scientific interventions that incorporate farmers' knowledge so as to improve productivity in these areas, shifting from a purely technical to a more inclusive approach (Barrios et al., 2012; Ginger, 2014).

In this chapter we explore farmers' local knowledge of the challenges they face in intensifying their farming systems, the livelihood strategies they employ to sustain their households, and the opportunities within these systems for enhancing agricultural productivity. Our aim was to combine local and scientific knowledge in order to design innovative interventions that are customized to local context and circumstances (Coe et al., 2014). The research was designed to inform activities being undertaken and planned by the CGIAR research program Humidtropics and its partners in Western Kenya.

Methodology

Site selection

Research was conducted across four villages in Western Kenya: Urudi and Bar Ohinga villages in Kisumu County and Uradi A and Ojalo villages in Siaya County. The four sites were all dominated by agricultural activities with similar crops being grown and livestock kept and were selected based on variation in vegetation cover, soil types, and market access. Mixed farming systems dominated in all villages and livestock was mostly local, and sometimes improved, breeds of cows, goats, and chickens. In Kisumu County, Bar Ohinga had visibly more forested areas than Urudi where there were fewer trees on farms and more intensive crop cultivation. Urudi had better access to market centres than Bar Ohinga. In Siaya County, Uradi A was a good representation of villages in the area in terms of soil type (red clay) while Ojalo had different soil types. Uradi A had better access to market centres than Ojalo. As a whole, the sites appeared to be fairly representative of the humid tropics where farming activities tend to be integrated (combining trees, crops, and livestock) and land use is intensive.

Local knowledge acquisition

Knowledge about agro-ecological interactions at the farm and landscape level was elicited from smallholder farmers, whose livelihoods are largely dependent on mixed farming systems, using the Agro-ecological Knowledge Toolkit (AKT), a knowledge-based systems approach (Sinclair and Walker, 1998; Walker and Sinclair, 1998; Dixon et al., 2001). Three stages of the AKT methodology were applied and complemented with participatory rural appraisal methods. The initial 'scoping' stage included a transect walk across each of the villages with the aid of a village leader and/or community worker. Single sex focus group discussions (FGDs) were held in each of the villages, with youths actively involved in each group. Participatory methods used during these sessions included resource mapping, historical timelines, and seasonal calendar exercises. The second 'definition' stage involved setting the boundaries to the study and deciding the sampling strategy which was purposive, with informants stratified according to topography (lower, mid, and upper slope), farm size (small 0.1–1 ha and medium 1–6 ha), and gender. This led into the third 'compilation' stage involving an iterative cycle of semi-structured interviews with a purposive sample of 60 willing and knowledgeable people (15 in each of the four sites). Interviews were processed and knowledge represented in two knowledge bases using the Agro-ecological Knowledge Toolkit software (AKT5), and then analyzed descriptively using the software's inbuilt tools (Sinclair and Walker, 1998; Walker and Sinclair, 1998).

Results

The knowledge bases contain a combined total of 635 unitary statements representing the knowledge of 60 farmers. The majority of statements (74%) show farmers' explanatory knowledge about agro-ecological interactions within their direct environment, while other statements serve to describe attributes of trees, livestock, and crops that they had experience of. In this section we start by characterizing the study sites and then move into looking more deeply at the shared and site-specific challenges and opportunities for enhancing livelihoods in the study area.

Shared and unique features within the sites

The four study sites shared some common socio-ecological features but also had some significant differences (Table 12.1). They all experienced a bimodal rainfall pattern; long rains from March to June and short rains from September to November. Although the rains tended to be within the same range of months of the year, they were of different durations across the sites. Soil types

Table 12.1 Farm characteristics and challenges and opportunities for sustainable intensification in four villages in Western Kenya

Bar Ohinga village (1440–1474 masl – gentle to steep slopes – red loam and murram soils)				*Urudi village (1456–1503 masl – gentle slopes – red loam soils)*			
Component	*Description*	*Challenges*	*Opportunities*	*Component*	*Description*	*Challenges*	*Opportunities*
Crops	Maize, beans, sorghum, cowpeas, sweet potatoes, groundnuts, slender leaf rattlebox	Wildlife raids by monkeys, baboons, and weaverbirds; low profit from maize and beans sales due to exploitation by brokers; low prices due to market flooding (lack of crop diversification or specialization); insect pests such as stem borers and aphids; diseases (East African cassava mosaic virus); parasitic weeds (*Striga hermonthica*); water scarcity	*Identified by local people:* Alternative livelihoods like bee-keeping to reduce reliance on crops *Identified by researchers:* Improve integration of farmers in crop value chains and formation of cooperatives for collective marketing; integrated pest management; introduction of disease resistant crop varieties; integrated weed management	**Crops**	Maize, beans, cowpeas, cassava, sweet potatoes, soya beans, *sukuma wiki*, nightshade, slender leaf rattlebox	Scarcity of cropland; low yields due to declining soil fertility; pests and diseases affecting crops and livestock; parasitic weeds (*Striga hermonthica*); water scarcity	*Identified by researchers:* Integrated pest management; introduce disease resistant crop varieties; integrated weed management; enhance existing kitchen gardens

Livestock	Local and improved goats, local and improved cows, local chickens, rabbits	Wildlife raids on free-range chickens; inadequate water resources	*Identified by local people:* Intensify chicken production through cage system *Identified by researchers:* Train and build capacity on rainwater harvesting techniques	**Livestock**	Local and improved goats, local and improved cows, local chickens, Kenbro chicken	Limited land for grazing livestock and keeping free-range chickens; low milk production	*Identified by local people:* Intensify chicken production through cage system *Identified by researchers:* Intensify dairy farming in zero grazing units
Trees	Woodlots (mostly *Eucalyptus* spp.); natural forest; boundary planting (*Markhamia lutea, Grevillea robusta*); home compound (*Mangifera indica*, *Persea americana*)	Indigenous forest species threatened by charcoal production; low profit from mango fruit sales due to exploitation by brokers; poor access to tree germplasm; pest and disease in *Mangifera indica*	*Identified by researchers:* Invest in fuel efficient stoves and/or use local waste to make briquettes instead of using charcoal; improve integration of farmers in fruit value chains and market access; establish tree nurseries within the village; improve advisory services about tree pests and diseases	**Trees**	Woodlots (*Eucalyptus* spp., *Grevillea robusta, Casuarina equisetifolia*), boundary planting (*Grevillea robusta, Euphorbia tirucalli*); home compound (*Persea americana, Senna siamea, Casimiroa edulis*)	Poor access to tree germplasm; *Eucalyptus* spp. competes with crops; scarcity of land for planting trees; low resources for firewood; disease affecting *Persea americana*	*Identified by researchers:* Establish tree nurseries within the village; improve advisory services about tree pests and diseases; outsource alternative sources of fuel energy (e.g. LPG gas); invest in fuel efficient stoves

(*Continued*)

Table 12.1 (Continued)

Uradi A village (1299–1358 masl – flat to gentle to steep slopes – red clay soil)				*Ojalo village (1281–1341 masl – gentle slopes – red clay, black cotton, mixed brown soils)*			
Component	*Description*	*Challenges*	*Opportunities*	*Component*	*Description*	*Challenges*	*Opportunities*
Crops	Maize, beans, groundnuts, sorghum, cassava, sweet potatoes, cowpeas, traditional vegetables (e.g. slender leaf rattlebox)	Scarcity of land; low profit from maize and beans sales due to exploitation by brokers; low prices due to market flooding (lack of crop diversification or specialization); pests and diseases affecting crops and livestock; parasitic weeds (*Striga hermonthica*); limited water sources	*Identified by researchers:* Improve integration of farmers in crop value chains and formation of cooperatives for collective marketing; integrated pest management; introduce disease resistant crop varieties; integrated weed management; train and build capacity on rainwater harvesting techniques	**Crops**	Maize, beans, cassava, sweet potatoes sorghum, kales, traditional vegetables	Competition from gold mining for labour and land; low yields due to declining soil fertility (top soils are mixed with mined soils); pests and diseases affecting crops and livestock; parasitic weeds (*Striga hermonthica*)	*Identified by local people:* Promote alternative livelihoods like fish farming and bee-keeping *Identified by researchers:* Plant trees and bananas for rehabilitation after gold mining; crop diversification; integrated pest management; introduce disease resistant crop varieties; integrated weed management

Livestock	Local breeds of cows, goats, sheep, and chickens, free-range grazing mainly practiced	Lack of water resources; pests and diseases	*Identified by researchers:* Train and build capacity on rainwater harvesting techniques; improve efficiency of extension services	**Livestock**	Local breeds of cows, goats, sheep, chickens, and pigs; some improved breeds of cows and pigs	Pests and diseases affecting livestock	*Identified by local people:* Improve efficiency of extension services *Identified by researchers:* Intensify dairy farming in zero grazing units
Trees	Boundary planting of *Euphorbia tirucalii, Markhamia lutea*, home compound (*Mangifera indica, Persea americana*); woodlots of *Eucalyptus* spp. on some farms	Poor access to tree germplasm; inadequate water for tree nurseries; limited land to plant trees	*Identified by local people:* Establish tree nurseries within the village *Identified by researchers:* Rainwater harvesting to provide water for tree seedlings; establish a tree nursery of multipurpose trees suitable for integrating on small farms	**Trees**	Boundary planting of *Markhamia lutea;* home compound (*Mangifera indica, Persea americana*); woodlots dominated by *Eucalyptus* spp.	Poor access to tree germplasm; destruction of young trees by free ranging livestock	*Identified by local people:* Establish tree nurseries within the village *Identified by researchers:* Increase protection of trees from livestock; establish a tree nursery of multipurpose trees suitable for integrating on small farms

ranged from red clay, red loam, murram (gravelly lateritic material) to mixed brown clay soils (Table 12.1).

The terrain varied from gentle sloping to steep within different parts of the villages. The average farm size of informants was 0.9 ha (ranging from 0.05 ha to 6 ha). The dominant farming system was mixed cropping with farmers utilizing their small lands for both subsistence (e.g. maize, beans, groundnuts, cassava, bananas, sorghum, sweet potatoes, and green vegetables) and cash crops such as fruit trees (e.g. mango and avocado), and for keeping livestock (e.g. cows, goats, sheep, poultry, and, in one village, pigs). The main agricultural land use practices were annual cropping, woodlots and boundary tree planting, and livestock keeping which was done through a mixture of zero grazing, tethering systems, and free grazing. Tree density was generally low with trees planted in homesteads, along farm boundaries, scattered on crop fields, and in woodlots, but it did vary widely between the four villages. Bar Ohinga village, for example, in contrast to the other three sites, had more tree cover with indigenous trees in forested areas (some species enrichment had also taken place) and exotic species in woodlots. Small-scale rock mining was commonly practiced alongside farming activities. Water was a scarce resource in Bar Ohinga and Uradi A villages. Zero grazing of dairy cows was mainly practiced in Urudi village while free grazing was practiced in the other three villages. Gold mining was unique to Ojalo village.

Constraints and opportunities for increasing agricultural productivity

It was found that farmers faced site-specific as well as shared challenges that acted as constraints to increasing agricultural yields to meet household needs and generate cash income. There was a mixture of natural resource based issues as well as labour constraints and market influences. Besides being knowledgeable of the challenges they were facing, farmers were also willing to discuss ideas for resolving some of the challenges and improving agricultural production/livelihoods in their local areas. Where farmers were not able to offer potential solutions, the researchers identified opportunities based on the challenges posed by them (Table 12.1).

Common challenges and potential entry points

The common challenges identified by people across the four sites were: high population pressures and land fragmentation; decreased soil fertility; and pests and diseases affecting crops (Figure 12.1). Increasing populations had led to land fragmentation through subdivision of land based on male lineage, subsequently leading to agricultural intensification efforts in order to provide enough food for the households. The continuous cultivation of land rather than allowing fallow periods was having negative impacts on soil fertility, in turn leading to decreased crop yields. External inputs were considered expensive and out of reach for most farmers. Low crop yields meant that harvests were mainly used

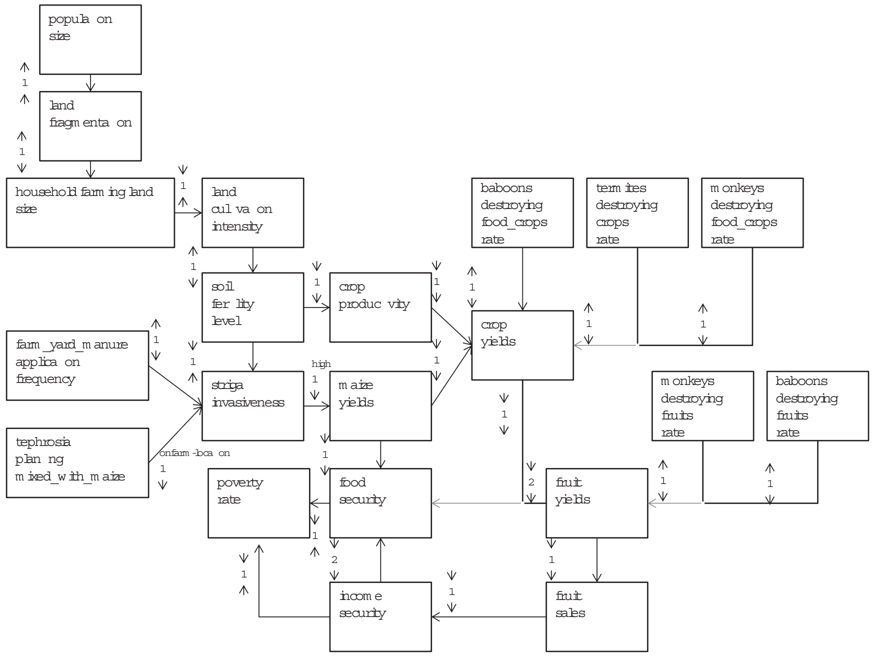

Figure 12.1 Causal diagram showing the agro-ecological interactions expressed by farmers and the challenges they faced when cultivating crops in Nyahera sub-location, Kisumu, Kenya. Nodes (boxes with straight edges) represent attributes of objects, processes, or actions; arrows connecting nodes show the direction of causal influence. The first small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the second refers to the effect node. An asterisk (*) indicates attributes of objects processes or actions that do not have an increase or decrease value. Numbers between small arrows indicate whether the relationship is two-way (2), in which case an increase in A causing a decrease in B also implies that a decrease in A would cause an increase B, or one-way (1), where this reversibility does not apply

Source: Nyahera knowledge base.

for subsistence purposes rather than having surplus to sell at markets to earn cash income. Small landholdings also negatively affected the incorporation of trees on farms as trees were said to take up a lot of space on land that could otherwise be used for food crops.

Land shortages and decreasing farm sizes due to population pressures were an issue across sites but there appeared to be different entry points for potential sustainable intensification measures. In Urudi and Bar Ohinga, kitchen gardens were a common practice for household vegetable production unlike the other two villages. There was observed to be opportunities for enhancing the existing practices using raised beds and knowledge sharing between sites. Small farm sizes also posed a challenge to farmers keeping livestock and a move towards zero grazing and more intensive chicken farming were seen as potential opportunities for increasing production (Table 12.1).

Building ecological resilience into the system, such as soil fertility improvement practices using integrated nutrient cycling approaches, and looking into proper soil/land management techniques, has been said to be a pre-requisite for sustainable intensification (Folke, 2006). Combining proven and effective methods to make agriculture more productive, attractive, and sustainable, and also to prevent the natural environment from further degradation, was identified as a pressing issue by the researchers in discussion with farmers.

Pests and diseases were major challenges affecting both crop and livestock production. Maize was highly affected by stem borers while aphids were a nuisance pest especially to beans, cowpeas, kale, and nightshade. Weaverbirds affected sorghum and millet. Ticks, mites, and tsetse flies affected cows. Although farmers did not know the names of all the diseases affecting their crops, trees, and livestock, symptoms included: wilting in maize and beans, rolling of bean leaves, yellowing of bean leaves and some leaves appearing burnt, bean rot, stunted growth in maize, swelling of the crop, and diarrhoea in chickens. The diseases with known names included: cassava mosaic disease; bacterial wilt affecting tomatoes and Irish potatoes; blight in tomatoes; halo blight in beans; yellow sigatoka in bananas; mastitis and foot and mouth disease in cattle; and typhoid in chickens. Pests and diseases were also affecting mango productivity and profitability in Bar Ohinga and the same for avocado in Urudi (Table 12.1). Most farmers were not able to afford pesticides and disease treatments so their crops, trees, and livestock would suffer as a result, inevitably impacting their livelihoods. Based on these challenges, improving advisory services regarding the identification of pests and diseases and effective and affordable control methods would be of great benefit to these communities.

Farmers reported that maize yields had decreased significantly due to the presence of Striga, a parasitic weed that causes stunting in maize and millet crops. The cause of this weed was unknown though some farmers attributed its increase to the use of inorganic fertilizers (which may itself be related to low soil fertility). Although most farmers interviewed did not know how to control Striga, some had observed a decrease in its occurrence when using organic manure (Figure 12.1). The need for advisory services and knowledge sharing on control methods was also very apparent in this case.

To address the issue of Striga, integrated weed management by combining push–pull technologies and livestock manure could be a viable intervention (Hassanali et al., 2008). A similarly integrated approach would also be feasible for pests and diseases, whereby repellent plants are intercropped and others are used to 'pull' and trap pests or disease vectors around the perimeter of the crop (Glover et al., 2012; Pickett et al., 2014). Research organizations based in the region were carrying out demonstration trials of push–pull technologies in the study area, led by the International Centre of Insect Physiology and Ecology (icipe), so this may lead to wide adoption of the technology if accepted by farmers.

Site-specific challenges and potential entry points

The main challenges discussed by farmers specific to some of the villages included: crop raids by wildlife; water scarcity; overexploitation of natural forests; firewood scarcity; small-scale gold mining taking labour away from farming activities; and exploitation by 'middlemen' when marketing their products (Table 12.1). Besides mentioning the challenges there was also discussion around potential opportunities for positive change.

WILDLIFE HUMAN CONFLICTS

Although Bar Ohinga village experienced bimodal rains, meaning it was possible to have two cropping seasons per year, crop yields were limited due to raids by monkeys and baboons (Table 12.1). These animal pests caused huge damage and farmers were abandoning crop production in order to limit losses. It was not only agricultural crops that were affected by baboons; they also attacked chickens and made free-range chicken production unviable. Farmers were not compensated for their losses by the government by any means and this had resulted in feelings of resentment and anger.

The researchers identified a need to come up with practical solutions for reducing human–wildlife conflicts without damaging wild animal populations (Hoffman and O'Riain, 2012). Farmers could potentially consider adopting non-food crop production and/or venture into alternative means of livelihood like bee-keeping; this was something people were interested in being trained on (Table 12.1). Some farmers were already opting to concentrate on petty trade of fish, fruits, and vegetables sourced from neighbouring villages while others sought off-farm employment in the urban centres.

WATER MANAGEMENT

Water scarcity was a major challenge in Bar Ohinga and Uradi A. In Bar Ohinga, this was attributed to erratic rains and the absence of any local water sources. Water was sourced from boreholes in a neighbouring village at a fee and it took on average an hour to and from the nearest water source. Out of the 15 farmers interviewed in Bar Ohinga, two had modern rainwater harvesting tanks while 11 had old water harvesting tanks and two had none. There was evidently some knowledge about rainwater harvesting but the water harvested could not last these households for more than a week and those interviewed were asking for support to buy newer tanks. In contrast, Uradi A village had one spring and one borehole where residents drew water for domestic use, but out of the 15 farmers interviewed in this village, only three farmers practiced rainwater harvesting using tanks or gutters along the roof for collecting rainwater. This lack of water storage led to water shortages particularly during the dry season when the water volumes of the spring and borehole would run low. To curb the challenges of water scarcity, farmers expressed the need for training on water harvesting and to be supported with water harvesting equipment.

FOREST AND ON-FARM TREE RESOURCES

Charcoal production was a major economic activity in Bar Ohinga, particularly since crop production was not feasible due to wildlife raids; however, the activity posed a threat to natural forests and the indigenous treespecies they harbour. Lack of firewood for domestic use was a major challenge in Urudi, although trees such as *Grevillea robusta* and *Senna siamea* have been planted on the farms, and farmers opted to buy firewood or to trade their products (e.g. avocados) for firewood in neighbouring Bar Ohinga. It was explained that the small farm sizes constrained planting of trees for firewood in Urudi. Although this was often given as the main reason, there did appear to be interest in establishing local tree nurseries to improve access to tree germplasm and this could be an opportunity to identify suitable agroforestry species for integrating on small farms (this was largely applicable across sites). Due to limited land availability for planting more trees, and the need to reduce pressure on existing forest resources, an option could also be the adoption of alternative fuel technologies such as fuel efficient stoves (Abdelnour and Branzei, 2010) and/or using local waste to produce briquette (Njenga et al., 2009), to solve the firewood and charcoal problem.

LABOUR SHORTAGES AND LAND USE CONFLICTS

Competing land uses and labour shortages were major challenges in Ojalo village where small-scale gold mining was a major economic activity. Gold mining had started in the late 1990s and was gaining popularity due to the discovery of economically viable deposits. Men were mainly involved in the mining, which was a very labour intensive activity, while some women would help in the digging and carrying of the soil. This resulted in on-farm labour shortages. The burden would fall on women to maintain the farm but when farm work was too much, and there were no resources to hire labour, essential tasks such as ploughing or weeding would not be done. This had an effect on the overall productivity of the farms. In addition, those involved in mining were not sure where gold deposits were located so holes had been dug haphazardly on farms. This was resulting in wastage of limited land that would have otherwise been used for crop production. While some famers were planting bananas in the holes, others were leaving them open. They explained that gold mining had a negative effect on the composition and fertility of the soil. Unfertile soil dug from deep layers of the soil was mixed with relatively fertile topsoil, leading to reduced soil fertility. Based on what was observed and discussed with farmers, planting trees and bananas to rehabilitate areas after gold mining appeared feasible and farmers were interested in alternative income sources, for example bee-keeping and fish farming (Table 12.1).

MARKETING FARM PRODUCE

In Uradi A village the main cash crops were maize and beans, with little diversification from these staples. Due to flooding of the market with the same products at harvesting time, low prices were common and discouraged farmers from selling their produce. Some farmers were able to store their maize and beans for up to three months after harvesting which meant they could sell later at a higher price. Urudi village had a similar issue with avocados and Bar Ohinga with mangoes; in these cases, middlemen took advantage of opportunities to exploit farmers by buying from them at very low prices and reselling at high profits. Avocados being highly perishable goods, it was said to be difficult to store them to sell later on and there was no local fruit processing plant. Producers therefore felt exploited. One way of tackling exploitation and low prices could be through forming cooperatives for marketing farm produce; coupled with value addition this could increase market returns for products such as mangoes and avocados. Further, diversification of crops could also be a viable option for reducing both losses incurred due to flooding of markets with similar crop products and those from wildlife raids.

Discussion

Using integrated approaches to resolve complex agricultural challenges

The knowledge elicited gives insights into the challenges people were facing in intensifying their farming practices and brought to light potential entry points for improvement of food security and incomes of smallholder farmers in Western Kenya. With rapidly growing populations, pressure on the natural resource base has been increasing in the region for many years (Conelly and Chaiken, 2000). The impacts of this are evident in the low agricultural productivity, not to mention poverty and malnutrition levels of these rural communities, because of poor natural resource management practices (Bloss et al., 2004). As demonstrated by Lambin and Meyfroidt (2011), there are ways of economically developing while at the same time protecting the natural resources (e.g. forests, agricultural land, water sources) that people are reliant on, but there needs to be effective policies in place for this to happen.

As mentioned earlier, previous studies have shown a clear threshold in terms of farm size for households to satisfy their income and food security objectives from agriculture alone (Waithaka et al., 2006). Of the 60 interviewed households in the present study, 33% had farms of less than 0.4 ha in size and almost half of these were in Ojalo village. This serves to demonstrate the very real challenges farmers face in sustaining their livelihoods through farming and the need to seek alternative sources of income if landholdings are small. As presented in the results, options could include venturing into activities that do not require much land such as chicken, bee-keeping, and fish farming, or engaging in off-farm activities to supplement what people get from agriculture.

Similar to smallholders in other parts of SSA, mixed farming systems in Western Kenya have been widely adopted with little to no specialization (Conelly, 1994). A lack of specialization and marketing prowess explains why a majority of the farmers interviewed in Uradi A and Urudi villages produced similar products leading to flooded markets and low prices. Similar to earlier studies in Western Kenya (Kongstad and Mönsted, 1980; Francis and Hoddinott, 1993; Conelly, 1994; Crowley and Carter, 2000), this study revealed that with decreasing land productivity, coupled with unviable highly fragmented small landholdings, farmers are gradually abandoning agriculture for other on-farm and off-farm activities, such as rock and gold mining. However, if alternative and viable ways of making a living from these small farms were presented and advisory services were improved in the area, perhaps land productivity could be improved while also meeting livelihood needs. There is a need for integrated approaches to ensure sustainable agricultural production.

Best practices in terms of soil fertility management using improved crop varieties, fertilizers, and organic inputs adapted to local conditions need to be shared (Vanlauwe et al., 2014). An essential component of building ecological resilience of soils is through promoting the use of organic material for building soil organic matter and promoting nutrient cycling to complement inorganic fertilizer use (Pretty and Hine, 2001; Folke et al., 2010; Pretty et al., 2011). Farmers lacked access to inputs such as chemical fertilizers due to high cost so this is an area that would need addressing. Pretty et al. (2004) argue that smallholder farming systems can increase and sustain production when farmers are provided with inputs. Research organizations and the government should therefore invest more in providing the farmers with the necessary support and subsidized inputs for increased production (The Montpellier Panel, 2013).

There is also the need to invest in integrated management regimes to control pests, weeds, and diseases using locally available, easily accessible, and affordable technologies (Pretty et al., 2011; The Montpellier Panel, 2013). The results of the present study concur with several authors (Berner et al., 1995; Khan et al., 2006) who found that Striga causes major damage to maize, which is a major staple food crop for households in Western Kenya. Intercropping two or more crops at the same time, e.g. maize and beans or maize and *Desmodium* spp., has been shown to reduce the risk of total harvest losses due to Striga (Khan et al., 2006; Khan et al., 2009). According to Waithaka et al. (2007), high soil organic matter content tends to reduce Striga infestation, which is in agreement with those farmers using organic fertilizers who reported a decrease in the occurrence of the weed. In addition, manure and crop residues release nutrients to the soil slowly and help soils to build organic matter with long-term benefits (Palm et al., 1997; Place et al., 2003). Exposing farmers to information on improved farming methods could help in pest, weed, and disease control efforts (Chitere and Omolo, 2008). Sharing such knowledge is vital if smallholder farmers are to address the challenges they are facing. Not only is it important to recognize the role that local knowledge can play in informing scientific research, scientific research also needs to be communicated through appropriate channels to those people that would benefit from the results.

As shown, crop raids by wildlife have caused huge economic losses to farmers in parts of Western Kenya. Although governments have policies on enhancing wildlife's societal values, there is also a need to understand the underlying drivers of human–wildlife conflicts and how this can be mitigated (Terry, 2000).

This would ideally lead to the design of conflict resolution policies that are integrated in nature, including compensating farmers for loss of crops to wildlife (Okello, 2005).

Charcoal production in many rural areas of SSA has been opted as an income-generating activity especially in poverty stricken areas. The activity has not been sustainable since the survival rates of charcoal producing tree species have been low. Also, not many people in these areas give priority to planting suitable trees since they are slow growing (Iiyama et al., 2015). These challenges coupled with poor policy environment have led to overexploitation of naturally occurring tree species. To resolve these paradoxes, there has to be an understanding of the causes of engaging in charcoal production, and incentives that can be used to reduce poverty-driven charcoal production (Iiyama et al., 2015).

Water scarcity is a major problem not only in Western Kenya but also across other parts of SSA where smallholder farmers rely on rain-fed agriculture (Helmreich and Horn, 2009). Rainwater harvesting technologies have been shown to play a key role in addressing this challenge, especially in the wake of a changing climate and unreliable rainfall (Malesu et al., 2007; Thorlakson et al., 2012). Simple techniques such as roof catchments using corrugated iron sheets and ground surface collection are very feasible in many rural areas of developing countries since they are suited to local conditions (Sturm et al., 2009).

Wood products have continued to be the most universal fuel for rural areas in developing countries (May-Tobin, 2011). With the decreasing lands for retaining only trees, trees on farms are increasingly becoming popular worldwide and agroforestry practices have been shown to help in meeting firewood needs and reducing pressures on natural forests (May-Tobin, 2011; Zomer et al., 2014). However, social and economic demands such as firewood, fodder, soil nutrients, and other needs need to be considered before steps are taken to promote a particular practice and invest heavily in its adoption (The Montpellier Panel, 2013). Whenever integrating trees on farms is not feasible due to extremely small pieces of land owned by individuals, adopting alternative sources of fuel energy for cooking would be a good solution. These can be sources like biogas, high-density pellets, and ethanol gas (Ministry of Energy and Petroleum, 2015). It is not enough for local people to merely be consulted on the integration and management of any chosen practices; they should be involved in the actual choosing of the practices to ensure their needs are met and uptake is successful (The Montpellier Panel, 2013).

Conclusion

The study revealed common challenges across the four villages relating mainly to land scarcity, decreased soil fertility, and pests and diseases in staple crops and fruit trees. However, each village had its own natural resource management issues and dynamics, thus requiring customized approaches to improving productivity of the existing farming systems. Farmers had detailed knowledge of the challenges faced in crop and livestock production but had significant knowledge gaps in terms of pest and disease identification and control.

Access to knowledge about integrated soil fertility management and integrated pest and disease control, along with better integration of farmers in market value chains, would be important interventions to increase agricultural productivity and income at farm and village level in order to improve smallholder livelihoods in the target area. The study demonstrates the importance of local knowledge research to better understand fine-scale variation in farming and community (here village) contexts and the needs and thinking of farmers in order to identify locally relevant entry points for sustainable intensification of farmer livelihoods (Coe et al., 2014). This study also reveals the trade-offs between on- and off-farm activities, e.g. in relation to labour, emphasizing the need for assessing the wider livelihood context and aspirations when agricultural innovations and interventions are negotiated with local communities. Any interventions should also be sensitive to gender roles within the household to have the greatest impact. Further research is needed to test which interventions are best suited and most likely to be adopted for sustainable intensification and improvements of farmer livelihoods in the study areas (Kiptot et al., 2007).

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