Oil palm intercropping in Uganda – an assessment of farmer practices and suggestion of alternatives

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Summary

The expansion of oil palm in Uganda has undoubtedly brought economic benefits including jobs and import substitution among others, but these have been accompanied by negative social and environmental impacts. This brief is the latest in a series that has investigated these impacts, but is the first to propose new models of intercropping for Uganda. International experience shows that growing food or cash crops with oil palm in agroforestry systems can increase smallholder incomes, resilience and biodiversity and surveys show that farmers in Uganda are already experimenting and are ready to adopt intercropping on a wider scale.

This assessment was undertaken in July-August 2019 and heavily builds on desk studies of experiences elsewhere. It contributes to the understanding of socio-economic and environmental impacts of oil palm development in Kalangala, and in particular on local livelihoods. It further provides insights on whether experiences and lessons learned across the oil palm growing spectrum can be adopted to reduce risks of negative impacts in new hubs for oil palm extension such as in Buvuma, Buikwe and Mayuge districts. The study further offers recommendations for the proposed implementation of the ten-year National Oil Palm Project (NOPP).

Of the 40 farmers interviewed, 11 males and 12 females were practicing intercropping while 10 males and 7 females were practicing monocropping. Beans (Phaseolus vulgaris), sweet potato (Ipomea batatas) and maize (Zea mays) were the most common crops intercropped with oil palm although among those mentioned, only sweet potatoes were observed in the field. Field observations included banana (Musa acuminata), cassava (Manihot esculenta), coco yams (Colocasia esculenta) and sugarcane (Saccharum officinarum) as the other crops inter-cropped with oil palm. Interviews with KOPGT showed support for intercropping for the first 1 to 4 years of oil palm growth while OPUL was not in favour of intercropping.

With a farmer guide and a policy brief produced as part of the products from this study, the enactment of by-laws supporting food production using such models suggested may go a long way in supporting the government to achieve its objectives of driving the island population out of poverty. The core objective of the study was therefore to explore means to improve environmental health as well as food and nutrition security in the midst of oil palm growing.

Introduction

The boom in demand for vegetable oil has driven the expansion of oil palm cultivation globally (Trostle, 2008), and following massive growth in Indonesia and Malaysia, this is now spreading in tropical Africa. Uganda's annual demand for edible oil is currently 120,000 tonnes, some three times its annual production (Manishimwe, 2018). Furthermore, population growth and rising incomes suggest a 9% yearly growth rate in domestic and regional demand for vegetable oil and by-products such as soup (Daily Monitor, 2018). Thus, the government proposed a plan to develop palm oil for import substitution, and that production from even poor yielding areas could substantially exceed that from similar areas of annual oilseed crops. The best area for oil palm in Uganda was found to be the Lake Victoria islands, notably the Ssese islands of Kalangala district (IFAD, 1997).

Since 1998, the Government of Uganda has invested in domestic production and processing of vegetable oils to meet increasing national demand. The Vegetable Oil Development Project (VODP) is implemented by the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) as the national strategic effort to increase domestic production and address rural poverty and nutrition, implemented in Kalangala, Buvuma, and 51 other districts across Uganda. The oil palm component was delivered through a public–private partnership arrangement where the government took sole responsibility for acquiring land while the private sector partner, M/S BIDCO Uganda Ltd., committed to providing investments, resources and technology for oil palm development and value addition.

In Uganda, a partnership between Ecological Trends Alliance and Tropenbos International has helped to investigate the impacts, and offer solutions. This latest study builds on those that looked at impacts of oil palm expansion in Kalangala, and complementary livelihoods options (Namanji and Ssekyewa, 2017; Ssemmanda and Opige, 2017; Ssemmanda and Opige, 2018, Tropenbos International, 2018). This particular study follows the hypothesis that instead of extensive monoculture in oil palm, it would be more socially, economically and environmentally sustainable to practice intercropping with other crops especially for smallholder oil palm plantations.

Intercropping, is the cultivation of two or more crops simultaneously in the same field, and is common in Africa, the Americas and elsewhere (Francis, 1986; Vandermeer, 1989; Li et al., 2013). It is a practice or system that has been credited as a means of sustainable intensification (Knörzer et al., 2009; Martin-Guay et al., 2018), because a farmer who cultivates several crops will benefit from a more diverse diet, and will have different marketing strategies as compared to one who cultivates a monoculture with a single commercialization channel (Gonclaves et al., 2017).

There is clear potential for intercropping with oil palm. A situation analysis by the International Union for Conservation of Nature task force recommended studies on "the extent to which polycultural oil palm (intermixed with other crops or tree species) could improve environmental and biodiversity outcomes while maintaining yields" (Meijaard et al., 2018). Furthermore, following recommendations by Namanji et al. (2019), this explores the possibility and practicability of oil palm intercropping in Uganda. ACALISE (2019) found that intercropping was practiced by 41% of male and 46% of female farmers in Uganda, so the concept is widely understood, and its feasibility in oil palm production systems merits investigation.

Production began in 2003 when the Uganda Government, represented by the Vegetable Oil Development Programme (VODP), the vegetable oil manufacturers in Uganda (BIDCO Uganda Ltd.) and the Kalangala Oil Palm Growers Trust (KOPGT), agreed through a public–private partnership to establish oil palm on Bugala Island in Kalangala district as a means by the Government of Uganda to achieve its goal of improving commercial agriculture value chains (Vision 2020). In 2006, the actual establishment of oil palm plantations started with a nucleus estate of 6500ha and small scale outgrower farmers cultivating a further 3500ha, supported by the International Fund for Agricultural Development (IFAD).

Bugala is by far the largest of the 84 Ssese islands that make up Kalangala District. In the 1970s and 1980s, it had 13 forest reserves, fertile soils, and abundant rainfall (FoE, 2012). Changes in the landscape for oil palm production came with deforestation and less involvement in food crops. Recently, in 2018, another phase of support from IFAD has been extended to expand oil palm in other districts including Buvuma island and mainland areas.

Unlike Bugala which underwent deforestation to make way for oil palm plantations, on Buvuma, most of the landscape is an integration of food crops (Ssemmanda and Opige, 2018). This implies that oil palm production will replace smallholder farming which has dire consequences on the food security and nutrition status of islanders, as well as general community livelihoods on the island. Picking lessons from Bugala Island, research shows that oil palm development had negative consequences on the environment and community livelihoods (Ssemmanda and Opige, 2018). Furthermore, establishment of oil palm in other districts of Uganda has already commenced and will not probably stop. However, there is need to minimize further consequences of oil palm growing and improve livelihoods. According to ACALISE (2019), livelihood is the sustained capacity, assets, and activities required for the household to cope with and recover from stresses and shocks, while not undermining the natural resource base. This implies sustainable systems. The sole question is whether it is beneficial to intercrop food crops with oil palm rather than having complete monocropping in oil palm plantations. If so, which crops would be most suitable for intercropping with oil palm in the selected agroecosystem? And under what conditions? The aim of this study is therefore, to explore the means to improve environmental health as well as food and nutrition security in the midst of oil palm growing. In specific terms, this study is guided by 4 objectives.

Methodology

The aims of this research were fourfold. First, was to explore the experience of intercropping of oil palm with other food crops around the world, second to provide insights into models that can be applied in the case of Uganda, third to guide on how the National Oil Palm Programme (NOPP)and local stakeholders can apply intercropping options, and finally to use lessons, to project what the oil palm promoters (NOPP) and local stakeholders in our case study may gain or lose by implementing the intercropping option. Information generated from these objectives shall feed into a farmer sensitization guide for Buvuma Island and the proposed new oil palm hubs in the main land. The farmer guide can be used by the small-scale farmers, oil palm companies, NGOs and the government extension workers.

The qualitative study involved a review of literature on oil palm intercropping systems across the globe to generate secondary data. Since oil palm is a tropical crop, we purposively selected cases from Asia (Malaysia, Indonesia) and West Africa (Cameroon, Ghana and Nigeria). Cases of oil palm intercropping from these regions were reviewed and existing practices and models noted and categorized.

To generate both qualitative and quantitative primary data, we conducted an in-depth survey of oil palm-based intercropping and monocropping systems on Bugala, with an open-ended questionnaire guiding interviews with randomly selected oil palm farmers and key stakeholders such as extension workers from the Kalangala Oil Palm Growers Trust (KOPGT), and Oil Palm Uganda Ltd (OPUL) involved in large scale oil palm production. The survey aimed to understand the socio-economic background of respondents, agronomic practices of both intercropping and monocropping practitioners; projections on what farmers may gain or lose by implementing either intercropping or monocropping, and training received on either practice.

Information collected was correlated to respondent practices, to identify crops and conditions suitable for oil palm intercropping systems. Survey data will be used to inform future agronomic trials aimed at evaluating identified oil palm intercropping systems to come up with appropriate models for Uganda and Buvuma island in particular, and within the socio-economic concept of the smallholder farmer.

Of the two counties in Kalangala, Bujumba was selected, and the two sub-counties of Mugoye and Bujjumba where oil palm-based cropping systems occur. In each sub county, two villages were selected with at least 5km from each other, based on involvement or not with oil palm companies, with a total of four villages including Kagulube and Beta from Mugoye sub-county as well as those from Bujumba sub-county. In each village, smallholder farmers were interviewed, followed by random sampling of 10 farmers monocropping farmers, including those who did previously intercrop and who never intercropped at all. There was a total of 40 respondents at village level, plus 10 respondents including extension workers from KOPGT and large-scale oil palm producers from OPUL.

This research adopted a case study research design which data collected from structured interviews guided by a questionnaire with both closed and open-ended questions. These were face-to-face for selected key informants enhanced by focus group discussions, supported by field observations, digital photos and voice recordings. The questionnaire included the effect of (i) sole oil palm monoculture on the growth, yield and performance of oil palm, (ii) intercropping oil palm with other crops on growth, yield and performance of oil palm, (iii) intercropping oil palm with other crops on growth, yield and performance of food crops intercropped with oil palm, (iv) environmental, social and economic benefits due to intercropping, (v) environmental, social and economic gaps due to intercropping, (vi) environmental, social and economic benefits due to oil palm monocropping, (vii) environmental, social and economic gaps from oil palm monocropping, and (viii) additional data collected on training and inputs accessibility.

Validity and consistency tests established that the instrument included all the essential items (Taherdoost, 2016), identifying six respondents practicing intercropping or monocropping, with each questionnaire item assessed using a three-point scale including 'not necessary'; 'useful but not necessary'; and 'essential' (Taherdoost, 2016). The method of Lawshe (1975) was used to calculate the Content Validity Ratio (CVR) for each item, as follows.

$$\alpha = \left[{}^{N}\!/_{N-1}\right]\left[\int_X^2 - \sum \int_i^2, \Big/ \int_x^2 \square \right]$$

Where CVR=Content Validity Ratio; ne=Number of panel members including 'essential'; N=Total number of panel members. The minimum value of CVR is 0.05 so we eliminated all items not found significant at the critical level.

The Cronbach Alpha coefficient (Straub et al., 2004) was used to test for consistency of the instrument, basing reliability as≥0.60 (Straub et al., 2004). To calculate consistency, Cronbach Alpha is given by;

$$\int_i^2 = \text{Variance of individual item score}$$

Where N= Number of items on the instrument,

$$\int_x^2 = \text{variance of the total test scores}$$

Where $\int_x^2 \square$ =sum of variances of scores of individual items,

$$\text{CVR} = {}^{\text{ne} - \left({}^{N}/_{2}\right)}\Big/_{{}^{N}/_{2}}$$

Once translated, information was entered into a database, and the R commander statistical package was used to quantitatively analyse the data for descriptive statistics, correlations of identified conditions and factors, and to generate tables, frequencies and charts. Qualitative data was categorised into themes based on case, model category, benefits and gaps.

The major limitation of the study was the question of reliability, since interviews rely on personal opinion and can therefore easily bias results. To reduce this, the validity and consistency of the research instrument was tested using other research instruments including observations, focus group discussions and involving a diversity of categories of respondents, including oil palm and non-oil palm farmers in different villages. In addition, we gathered more views from proprietors of oil palm including large scale companies (OPUL). Another limitation was the politicisation of oil palm growing in Uganda. To overcome this issue, we endeavoured to explain to our respondents that the purpose of this study was to pave the way for a sustainable development path rather than political interests.

The biggest challenge was that small-scale farmers were not happy with researchers coming to collect information and never returning to solve their problems. Thus, some were reluctant to take part in the survey. This required having to go to their respective homes and patiently wait for attention, meaning more time than anticipated and so not all 55 planned interviews were possible. In addition, in some villages, it was not possible to have equal number of farmers in each category (intercropping and monocropping) because some were only monocropping (e.g. in Mulabana village), thus also affecting final numbers.

Results

Focus on literature

The literature review enabled an understanding of whether smallholder farmers can practice oil palm intercropping by showing how this has worked in similar tropical ecosystems around the world. It generated insights on models that can generate lessons for the case of Uganda, and provide guidelines on how the NOPP and local stakeholders can apply intercropping options.

According to FAO (2013), mixed tree and food crop farming systems have the potential to offer solutions to deforestation for plantation agriculture, since subsistence farmers are in position to gain income, nutritive and safe food security and environmental sustainability. Traditionally, there have been mixed cropping systems and these have various advantages both to the ecosystem and farmers (Francis, 1986). On a global scale, mixed farming systems have been observed to be advantageous in improving soil fertility, in pest and disease management, in mitigating climate change and in providing alternative income. For example, studies by Omar et al. (2010) showed that intercropping in oil palm maximizes land use and generates additional income for farmers.

To mitigate negative consequences in the environment, studies in Indonesia showed that intercropping oil palm with crops such as rubber increased carbon stocks by 37%, decreased nitrogen leaching by 66%, and improved erosion control by 57% (Slingerland, et al., 2019). Most recently Khasanah et al. (2020) showed with a modelling study that oil palm-cocoa intercrop planted in a double row avenue system in Indonesia provided a high land equivalent ration (LER) of 1.4 which means it is sparing 0.4 ha of land compared to monocultures. The intercropping system was also replenishing more ground water and had a lower carbon footprint. It had a return to labour equal to that in oil palm monocultures. Oil palm-cacao systems are less sensitive to price uncertainty for oil palm, and buffer for oil palm and cocoa production risks, assumed to be independent of each other. Very positive economic results were experienced in a model study for black pepper after 10 years of intercropping it with oil palm (Slingerland et al., 2019).

Intercropping allows farmers to diversify their incomes rather than depending on one crop, in addition to achieving environmental benefits such as biodiversity (Ashraf, et al., 2018), and conserve natural resources (ACALISE, 2019). While designing agricultural development projects, Orewa (2008) established the importance of involving farmers in undertaking agronomic practices that best suit their needs such as family food needs, maximizing returns from the use of labour and relative crop prices. This way, development change becomes more practical when it starts from the farmers' level of understanding and based on their needs at that particular point in time. This could call for the need to learn from farmers (Orewa, 2008). In the same study, it was established that from a number of studies, smallholder intercropping was found to improve “soil fertility, water retention and soil temperature, control of pests and diseases and enhancing agricultural productivity and discouraging herbivore build-ups” (Orewa, 2008).

Thus, intercropping oil palm with crops that have aggressive root systems such as cassava may not be successful unless if it was only done in the first two years. Scientifically shallow rooted plants compete with the palm plant for nutrients whereas deep tap rooted plants help to recycle nutrients which would otherwise be leached deeper into the lithosphere. In light of the above this study found the need to provide an insight on the models that have been tested elsewhere and could provide lessons for intercropping to be implemented in the case of Uganda.

In many reported cases in West Africa and Brazil, smallholders traditionally practice extensive oil palm-based agroforestry to make up their livelihood. In South-East Asia, however, mainly high-productive, profit-maximizing monocultures dominate the landscapes (Corley and Tinker, 2003). Nevertheless, in all growing areas some smallholders intercrop oil palm seedlings with non-permanent food crops like maize, manioc, yam, cocoyam, and soy bean to bridge the income gap until the oil palms start fruiting (Lal et al., 1992; Okpala, 1995; Salako et. al., 1995; Erhabor and Filson, 1999; Corley and Tinker,2003). This establishment intercropping, however, contributes little to a more heterogeneous structure which would benefit biodiversity (Phalan et al., 2009; Foster et al., 2011). A study by Nchanji et al., 2016 showed that farmers in Cameroon found it more rewarding to do intercropping than engaging in monoculture. Box 1 shows these findings

In a few experiments, oil palm was permanently intercropped with trees, thereby creating permanent diverse agroforests or less diverse combinations between just two tree species. In Malaysia, research shows that intercropping oil palm with black pepper in an adapted planting pattern, has the potential to diversify farmer incomes. Box 2 is a theoretical case in Malaysia. Malaysia is the largest global production centre of oil palm with47% of global production, followed by Indonesia with 36% (Yemadje et al., 2012) hence experiments in oil palm system in Malaysia may have large consequences for the entire sector

According to a documentary by the Uganda Broadcasting Corporation Television (Business News, 24 September 2019), farmers in Cameroon intercrop oil palm with white pepper which fetches about US$20 per kg. This example confirms the importance of price when choosing a species for intercropping. Other than intercropping oil palm with food crops, there is potential for intercropping with other trees that are beneficial to ecosystem functioning.

In Malaysia, Chia (2011) concluded that teak grows better as an intercrop with oil palm than in monoculture, with survival after ten years being 89% compared to 85% respectively, tree height of 18.2 m compared to 16.9, and

Efficacy of oil palm establishment intercropping by smallholder farmers: Case study in South-west Cameroon

Oil palm was rarely being planted as a monocrop (10 %) by smallholder farmers in the study site but it was being intercropped with annual food crops during the first three to four years (corresponding to the immature stage) of oil palm. This was previously reported by Cheyns and Rafflegeau (2005), who stated that ‘’in Cameroon, whether on family farms or on medium-sized farming enterprises, food crops are usually grown in most immature oil palm plots, either over the entire plot or in part of it’’. As shown in the results, intercropping generated income to people of all social class and age groups. Although women were limited by capital and land tenure and acquisition rights to own land, intercropping was particularly attractive to them because it involves minimal inputs in the form of capital and labour which women can provide. Intercropping is also beneficial to women in that the income obtained is normally used for general household upkeep and improved nutrition of the family. From the study, intercropping was mostly done for food and nutrition security, and as a means to raise income because of the delayed income earning of oil palm which is a major setback to oil palm cultivation (Nchanji et al., 2016).

Intercropping oil palm with black pepper in Malaysia

Black pepper starts producing 1-2 t/y during the first 3-5 years and before oil palm comes into production. At peak production, black pepper yields about 3 t/ha. Black pepper is a high value crop that has much higher price per ton than oil palm, therefore some decreases in oil palm yield in an integrated system compared to monoculture will be compensated by the additional income from black pepper. The exact compensation depends on the evolution of yields of oil palm and black pepper over time and market prices each year. Black pepper prices FOB Indonesia went steadily up from US$2000/t in 2006 to US$14,000/t in 2015, dropping to US$2700/t in October 2018 (www.agriwatch.com); and (about US$20,000/t in 2019 export market price). During the same time, palm oil prices fluctuated between US$350/t (2009) and US$500/t (2003-2016) and peaks of US$886 (2008, 2011, and 2013) traded at the Malaysian stock market (https://tradingeconomics.com/commodity/palm-oil). In the worst case scenario, with the palm oil peak price of US$886/t and lowest black pepper price of US$2000/t, one tonne of black pepper can still compensate for a 2.5 t decrease in palm oil production, equal to 12 t of fresh fruit bunches, whereas yield decreases of fresh fruit bunches at maturity never exceeded 5 tons (compared to monoculture) and black pepper yields at maturity are 3 t/ha. So, black pepper always more than compensates for the modest reductions in palm oil yields, and additionally, reduces dependency on volatile palm oil prices (Slingerland et al., 2019).

diameters of 30.2 cm compared to 28.6 cm. However, some caution is required interpreting these results. Firstly, the experiment was in a system with very low yields of fresh fruit bunches in monoculture of only up to 7 t/ha/yr seven years after planting, indicating that the system was not optimally managed. Intercropping then reduced oil palm yields substantially compared to monoculture from five years after planting, with yields of only 1 t/ha/y at nine years after planting. Based on this study, intercropping oil palm with tree species like teak is therefore NOT recommended as it will increase the tree density and create upper canopy competition between the oil palm fronds and the teak branches. In order to maximize land use and yield of oil palm, the recommended agroforestry system might be to plant the species in different blocks.

Teak (*Tectona grandis*) was one of the rarest tree species in a study carried out by Namanji et al. (2019) on Bugala island. At the time of the research, respondents mentioned that timber from this tree was imported from DRC at a high cost (UGX 80,000 per 14ft piece) because its timber was the best for making deep water fishing canoes. Intercropping oil palm with such tree species could provide solutions for income and environmental protection, because they are deep tap rooted and would also play a role in recycling of nutrients, as well as hosting nesting high value birds like parrots. Again, price and utility are important criteria to choose a species for intercropping and important environmental benefits may come along. Yet, as the study by Chia (2011) in Malaysia showed, the effect of intercropping on oil palm yield needs to be included in the assessment.

Several studies looked at oil palm-cocoa intercropping. No yield depression of oil palms was noticed when intercropped with cacao in Malaysia (Lee and Kasbi, 1980, cited in Teuscher et al., 2015) or in Ghana (Amoah et al., 1995, in Teuscher et al., 2015). In Ghana mature palms were intercropped with cocoa as underplanting. As palm trees were already well developed and of considerable height, this may explain why palms were not affected by the smaller cocoa trees. On the contrary cacao yields in these fields were affected and heavily dependent on oil palm density (Amoah et al., 1995 in Teuscher et al., 2015): Cocoa in the lowest density (105 palm trees per ha) showed 5-6 times more cocoa pod and bean yield than in the highest, normal, oil palm density (148 palm trees per ha). In Nigeria, reported cacao yields were higher when planted under oil palms (Egbe and Adenikinju, 1990 in Teuscher et al., 2015) than in monoculture due to beneficial effect of shading. However, they did not report potential effects on oil palm yields and oil palm tree density was relatively low compared to oil palm monoculture.

In oil palm-rubber intercropping, negative effects from light competition were reported for both species (Corley and Tinker, 2003 in Teuscher et al., 2015). In Indonesia, native species including *Aquilariamalaccensis* and Shorea sp. were reported to grow well under oil palm (Muryunika, 2015). Elsewhere, in Sumatra, Teuscher et al. (2015) found about half of oil palm smallholders retained trees in their plantations, which benefits biodiversity but results in revenue penalties due to lower yields, and although interested in intercropping with other trees, there were no approved guidelines nor any knowledge about the ecological and socio-economic costs and benefits of oil palm agroforestry.

From a financial perspective, intercropping with black pepper offers a buffer against price fluctuations, and compensates for losses in palm oil yields. Teak (*Tectona grandis*) also fetches a good price, but only after many more years. So, the benefits of teak need to be balanced with oil palm yield losses not only in absolute terms but also taking into account when the benefits occur (palm income is monthly, teak is only once at felling). Furthermore, teak-oil palm experiments need to be done in well managed plantations to separate the competition effect due to intercropping from yield penalties due to other factors. Oil palm-cacao intercropping showed varied effects depending on different tree configurations, including a double row avenue system in Malaysia, intercropping at plantation establishment or under-planting in Ghana.

- Combining oil palm with annual crops during establishment (1-5 years after planting) is 'win-win', filling the income gap till palm trees start fruiting, without affecting their growth and development.
- Combining other commercial trees with oil palm leads to reduced oil palm yields which need to be compensated for by the alternative revenues and non-monetary environmental benefits.
- Permanent intercropping of oil palm and other species will require different practices, such as double row avenues instead of triangular monocropping plantations, and/or lower oil palm densities.

Introducing intercropping

Establishing oil palm in new frontiers comes with contestation from local farmers, civil society organisations and the public, because of negative environment consequences and unclear land acquisition processes (de Vos, 2016). These contestations can be solved when companies promoting oil palm encourage farmers to undertake intercropping as a way of involving farmers in the oil palm value chain (Slingerland et al., 2019), providing farmers some additional oil palm income while they can safeguard their multiple livelihood options. This practice benefits both small holder farmers and the oil palm companies. One of the systems recommended for intercropping is the double row avenue system (Suboh et al., 2009, in Slingerland et al., 2019). This allows farmers to intercrop within the oil palm such that they can still benefit from the additional income and food security without being excluded from oil palm production.

When oil palm was introduced to Indonesia in the 1900s, it caused land conflicts and negative environmental issues. There was need for inclusive growth and sustainable maintenance of land productivity. Therefore, oil palm companies began to integrate oil palm into landscapes other than monocropping plantations. The Indonesian company Bumitama Agri. Ltd moved into conservation projects by mapping out peat and forest areas and joining hands with local communities to adopt corporate social responsibility. One of the integrated activities was bird nesting for swiftlets which would be harvested for the hotel market coupled with ecotourism and rice production. Together with the community, effort was put on integrating oil palm with non-timber forest products such as mushrooms, and various vegetables, fruits, fibre and medicinal plants that originally grew in the forest and had value to the community (Aidenvironment, 2017). Unfortunately, no documentation could be found on the mentioned agronomic and socioeconomic performance of these integrated oil palm systems.

Another approach to applying intercropping options is by seeking knowledge on intercropping or what Kolb (1984) referred to as experiential learning. Slingerland et al. (2019) provide an example in their study on improving smallholder inclusivity through integration of oil palm with crops. They showed that it is important to test different crop combinations in experiments for the entire 25-year rotation of oil palm (Slingerland, et al., 2019). The WaNuLCAS model provides guidelines on this approach because it can predict the yield of each crop by focusing on competing factors such as water, nutrients, and light (Van Noordwijk et al., 2011 in Slingerland et al. 2019; Khasanah et al., 2020). The model also estimates other effects such as the cost of labour to estimate income per hectare and environmental effects.

Benchmarking global experiences of oil palm intercropping

Findings revealed three main intercropping models. These include temporary establishment intercropping, double row avenue intercropping, and complex agroforestry or home garden systems. An additional specific case is boundary cropping (see Table 1). Combinations between oil palm and conservation areas also exist based on mapping out areas for conservation and using the rest for oil palm as shown by Bumitama Agri Ltd. In Indonesia (Aidenvironment, 2017). Among the benefits were are promotion of ecotourism, ensuring bird nesting, conservation of non-timber forest products including vegetables, fruit, fibre and medicinal plant species, and production of different crops.

Table 1. Four oil palm intercropping models and their benefits for different studied cases.

Models	Cases	Associated benefits
Intercropping in immature oil palms, followed by monoculture oil palm at maturity	Many cases in all continents (Lal et al., 1992; Okpala, 1995; Salako et. al., 1995; Erhabor and Filson, 1999; Muryunika, 2015)	• Closes income gap between planting and first oil palm harvest (3-5 yr) • Annual crops such as maize, soybean, peanut, or multi-annuals such as banana and pineapple • Provides food for household use and market sales • May provide nutrients to palm (through N-fixing legume crops) • Provides soil cover preventing erosion • No negative effect on oil palm growth or development reported
Double row avenue intercropping (alley intercropping)	Malaysia (Suboh et al., 2009 in Slingerland et al. 2019). Indonesia (Muryunika, 2015)	• Allows farmers to intercrop permanently with minimum negative impact on oil palm yield • Choice of crop to minimise competition for light, water and nutrients • Choice for combinations with high value crops that can compensate for small reduction in oil palm yield • With timber trees as intercrop beware of competition
Complex agroforestry systems or home gardens	Indonesia (Teuscher et al., 2015) and Indonesia (Muryunika, 2015)	• Support many livelihood strategies (food, feed, timber, ...) • Provide resilience in income • In home gardens oil palm revenue is seen as a relatively high income additional to income from all other existing crops. Maximum oil palm yield/ha is not necessarily an objective • Fruit trees for social activities and sales • Income from other trees that are planted in conventional oil palm planting patterns will have to compensate for oil palm yield penalties
Boundary intercropping with trees	Indonesia (Muryunika, 2015)	• Timber for the future • Mainly for own use • Demarcation of land ownership • Environmental conservation function

Experiential learning of oil palm intercropping systems (WaNuLCAS Model; Van Noordwijk et al., 2011, In Slingerland et al., 2019; Khasanah et al., 2020), can be used to inform both temporary and permanent intercropping. WaNulCas enables understanding the impact of each intercrop and consequences in terms of yield of each of the crops. The model also provides information on environmental impacts. Using this model avoids the need for long term field experiments. The model also allows to calculate costs and benefits per ha, per unit of labour and over longer time periods. Beware, WaNulCAS cannot deal with highly complex home gardens which have multiple crop species.

Furthermore, common intercrops in oil palm were identified (Table 2), based on practices in Malaysia, Indonesia, Cameroon, Ghana and Nigeria. At least seven different commodities were found used as intercrops in oil palm in those countries. Such crops have variable effects on the performance of oil palm, different spacing patterns, economic values and different conditions of growth (Tables 2 and 3).

Table 2. Crops used as intercrops, their spacing, impact on oil palm and their economic values

Crop and duration	Source	Spacing(m) and/or density	Impact on oil palm/ intercrop*	Economic value of intercrop
Black pepper (permanent)	Malaysia: Slingerland et al., 2019	Oil palm9x9x6m in (double row), with 3 rows of pepper in the avenue.	1 (oil palm)	High value
Teak (permanent)	Malaysia: Chia, 2011	Oil palm 9x9m, teak 9x9m in alternating rows (i.e. 4.5x9m between palm/teak	4 (oil palm) 1 (teak)	High value
Maize, cassava, plantain (temporary, max 4 years)	Ghana: Nuertey, 1999	Palm 8.8x8.8x8.8m =130/ha Maize (0.7x0.5m) Cassava (1x0.7m) =945/ha Plantain (3x3x3m) = 88/ha	1 (oil palm) 1 (maize) 1 (cassava) 1 (plantain)	Low value Medium Low value
Cassava (temporary)	Nigeria: Sparnaaij, 1957; Onwubuya and Eneh, 1987; Ofo et al., 1988	Density unknown	2 (cassava shades oil palm and is in field many months a year)	
White pepper (permanent)	Cameroon: UBC, 2019	Supported by oil palm trees planted 8x8m	1	High value
Rubber (permanent)	Southeast Asia: Corley & Tinker, 2003, in Teuscher et al., 2015	Not given	2	Medium value
Cacao (permanent)	Malaysia, Ghana, Nigeria: Lee and Kasbi, 1980; Amoah et al., 1995; Teuscher et al., 2015. Indonesia: Khasanah et al., 2020	9x9x6m (double row avenue)	1 1 (oil palm) 1 (cocoa)	Medium value
Red meranti (*Shorea leprosula*) (permanent)	Indonesia: Muryunika, 2015	- 4x9m, in 8-yr old 9x9x6m double row oil palm, at 5y. - 4x9m, in 13-yr old 9x9x6 m double row	-Oil palm and meranti yields equal to monoculture -Oil palm yield higher than monoculture, meranti growth less	High value High value
Mahogany (*Swietenia macrophylla*) (permanent)		Border planting in 8-13-yr old 9x9x6 m oil palm, evaluated at 5 years	Mahogany growth lower than in monoculture especially in older oil palm plantation	High value
Jabon (*Anthocephalus cadamba*) (permanent)		Border planting in 8-13-yr old 9x9x6 m oil palm, evaluated at 5 years	In youngest palms already heavy growth depression of jabon compared to monoculture	Low/ medium value

* 1=Minor, compensatable; 2=Minor, not compensatable; 3=Major, compensatable; 4=Major, not compensatable

Table 3. Economic value of some oil palm intercrops

Crop	Country	Average market value per tonne (US$) and range, 2006–2019
Oil palm	Malaysia	$600 (350–886)
Black pepper	Malaysia and Indonesia	$12,730 (2000–20,000)
White pepper	Cameroon	$20,000
Teak	Uganda	$500 timber value per mature tree

Similar to findings by Nuertey (1999), farmers make a choice of intercrop based on factors such as the food culture of the area, the climate, soil, age of oil palm and socio-economic factors. Major lessons from this section are the following.

- In Ghana, intercropping with annual crops such as maize and cassava or banana in the establishment phase of oil palm (for three years) does not decrease yields of oil palm or of the intercrop, even when intercrop has not been fertilized (Nuerthey, 1999). Muryunika (2015) reports the same for Indonesia.
- Intercropping with trees requires different planting densities or yield penalties are expected for oil palm (Domestic trees in Teuscher et al., 2015; Teak in Chia, 2011), and may lead to penalties for timber trees also even when trees are just planted as border rows (Muryunika, 2015).
- Choice of intercrop is mainly based on economic value and their yields may compensate for losses in oil palm yield (e.g. black pepper, Slingerland et al., 2019) or not (e.g. teak, Chia, 2011).
- Land sparing occurs in certain intercropping systems compared to their monocultures e.g. oil palm-cacao with Land Equivalent Ratio of 1.4 (Khasanah et al., 2020) which is important to save forests and also greenhouse gas emissions related to land clearing.

Survey results

Demographics

There were 50 respondents including 40 farmers from four villages and 10 key respondents from KOPGT and OPUL (Table 4). Of the 40 farmers, 11 males and 12 females were practicing intercropping while 10 males and 7 females were practicing monocropping. This shows that in the category of farmers who carried out intercropping we got more (23) respondents than the 20 planned for, while in the category of farmers who practice monocropping we were able to interview only 17 respondents out of the 20 planned for. This was attributed to the limitation shown above where some farmers were reluctant to take part in the survey yet in some villages like Mulabana, all respondents were practicing monocropping. We accepted the total sample as it was since the difference in numbers between intercropping and monocropping farmers was not so significant to bias results. There were 5 respondents from KOPGT and 5 from OPUL, which made a total of 10 key respondents at those respective levels. At KOPGT we interviewed 3 males and 2 females. At OPUL we were able to interview only males.

Table 4 Demographic information of farmers, land size and their cropping practices

		Experience with intercropping	Only monocropping	Total
Village	Kagulube	10	0	10
	Beta	8	2	10
	Bujjumba	5	5	10
	Mulabana	0	10	10
	Total	**23**	**17**	**40**
Gender	Male	11	10	21
	Female	12	7	19
	Total	**23**	**17**	**40**
Age	28	1	0	1
	30-45	8	4	12
	46-55	11	5	16
	56-75	3	6	9
	76-85	0	2	2
	Total	**23**	**17**	**40**

cont. table 2

		Experience with intercropping	Only monocropping	Total
Land size (ha)	1-4	12	8	20
	5-8	9	4	13
	9-12	0	0	0
	13-16	0	3	3
	17-20	2	2	4
	Total	**23**	**17**	**40**
Years farming	3-5	4	3	7
	6-8	9	6	15
	9-11	7	3	10
	12-15	2	4	6
	21-25	1	1	2
	Total	**23**	**17**	**40**

Source: Primary data

Table 5. Frequency of various intercropping agronomic practices and intercrops

Variable		Frequency
Most common crops	Beans	3
	Potatoes	14
	Maize	3
	All of the above	3
Average years of intercropping	1-2	5
	3-4	17
	5-6	1
Common method of intercropping	In rows (9 x9m) between oil palms	21
	Weeding 1.5-2.0 m around tree	1
	Both in rows and circle weeding	1
Stage of intercropping	Immediately at planting	20
	After a few months of planting oil palm	3
Reasons for intercropping	Sustainable land use	12
	Optimize gain	7
	Both of the above	4

Results in Table 5 above show that beans (*Phaseolus vulgaris*), sweet potato (*Ipomea batatas*) and maize (*Zea mays*) were mentioned by respondents as the most common crops intercropped with oil palm although among those mentioned, only sweet potatoes were observed in the field. However, in the field other crops such as banana (*Musa acuminata*), cassava (*Manihot esculenta*), (Figure 3B and 3C), some cocoyams (*Colocasia esculenta*) and sugarcane (*Saccharum officinarum*) were observed. Among those mentioned, over 50% of respondent farmers intercropped sweet potatoes, but only 14% planted all three crops with oil palm.

Farmers carried out intercropping immediately after planting the oil palm, and for the majority of farmers, the average period of intercropping was 3-4 years, putting the intercrops between oil palm rows of 9x9m and based on the oil palm canopy size. Majority of farmers mentioned the need to use their land in a sustainable way as the major reason why they carried out intercropping.

Triangulating these results with those from KOPGT, beans and maize were mentioned as the most common intercrops. But other crops such as bananas, rice, cassava and ground nuts were mentioned as well. In addition, KOPGT extension workers mentioned the need for intercropping. Reasons they gave for smallholders practicing intercropping included: (i) the long duration before initial oil palm harvesting so needing alternative income from other crops, (ii) maximising land use., (iii) improving soil fertility including nitrogen-fixing from beans, and (iv) to control weed growth in plantations.

Intercropping methods mentioned by KOPGT were similar to those mentioned by smallholder farmers, except for mucuna (velvet bean) cover crop planting to improve soil fertility, prevent soil erosion and conserve water (Figure 3A). Respondents in all categories mentioned the visible long-term effect of oil palm on the growth of intercrops. Effects included the following.

- Crops such as beans, bananas, and sweet potatoes are suppressed under oil palm shade as trees grow older. As such, shade tolerant crops are recommend, like cocoyams, black pepper (*Piper nigrum*), vanilla (*Vanilla planifolia*), cardamom (*Elettaria cardamomum*), coffee (*Coffea arabica*) and turmeric (*Curcuma longa*), and for perennials amongst them, alongside adapted oil palm spacings.
- Crops were said to be in soil-nutrient competition with oil palm and did not mature well if grown too close to shallow rooted oil palm trees. In Ghana, Nuertey (1999) found that crops needed to be at 0.7 to 2.8 m distance from the oil palm tree depending on canopy size.

However, on a positive side, due to the regular pruning of oil palms, the remains would avail nutrients to complementary crops.

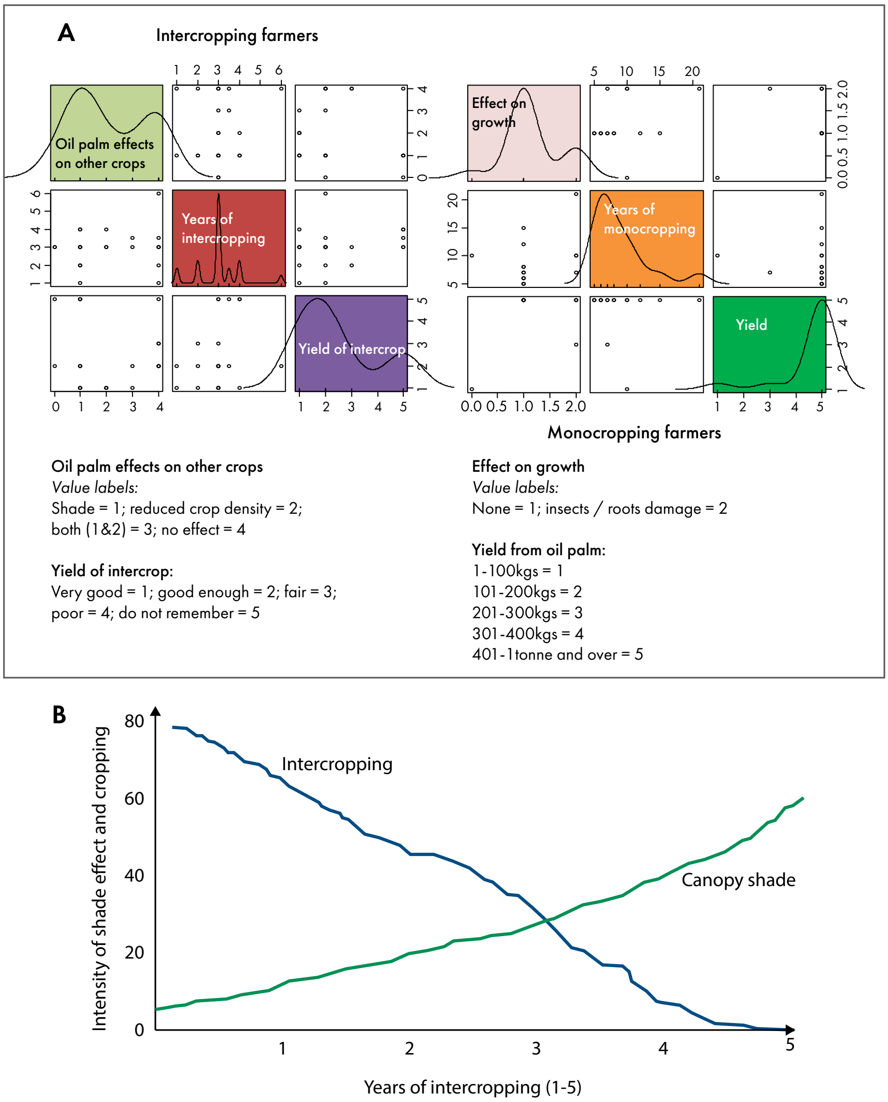

Figure 1. A - Years of intercropping and monocropping, yield of oil palm and other crops, oil palm effects on intercrops and intercrops effect on oil palm; B - Inverse relationship between canopy shade and intercropping intensity

Pictures (Figure 2A, 2B) show on the one hand that majority of farmers carried out intercropping for the first three years, and within those first years, they did not have any yield for oil palm but after 3-5 years, the yield of other crops was not good enough or intercropping was completely stopped, and furthermore Figure 2A shows that majority of farmers mentioned shade as the biggest effect of oil palm trees on the growth of other crops. Thus, when the oil palm canopy shade reaches intensity, crops like beans, maize, sweet potatoes and cassava cannot perform at all (Figure 2B).

Figure 2. Field examples of intercropping with oil palm including mucuna (a); bananas and sweet potatoes (b); cassava (c); possibility of ferns growing on the oil palm trees instead of a climbing crop (d).

Agronomic practices of farmers practicing oil palm monoculture

Most smallholder farmers practicing only monoculture had spent 5-8 years monocropping because they were following company directives which were against intercropping. Although Oil Palm Uganda Limited (OPUL) encouraged smallholder farming, results from all respondents from OPUL mentioned that the company did not encourage intercropping and gave reasons below.

1. The oil palm project included 60% of hilly and marginal soils that could not support multiple cropping
2. Heavy usage of machinery at particular points limits multiple cropping and harvesting
3. Oil palm would out-compete other crops for nutrients since oil palm is a heavy feeder on soil nutrients.
4. Fibrous roots of oil palm trees inhibit growth of some crops
5. Assurance of proper management of palm trees
6. Focus on maximizing oil palm yield since oil palm is purely a commercial crop
7. Oil palm is a perennial crop which needs a lot of spacing.

Table 6. Monocropping agronomic practices

Variable		Frequency
Average years of monocropping	5-8	11
	9-12	4
	13-16	1
	17-20	0
	21-24	1
Reasons for monocropping	A remedy for monkeys	2
	Company does not allow us	14
	Both as a remedy for monkeys and company restrictions	1
Practices	Spacing pattern of 9x9x8.5m for oil palm	
	Cover crop planting (*mucuna*)	
	Heavy application of balanced fertilizers and mill residuals (e.g. empty fruit bunches and boiler ash)	
	Terracing	
	Herbicide usage	
	Weekly harvesting	
	Pruning	
	Circle weeding	

All monocropping farmers mentioned common agronomic practices which include spacing pattern of 9x9m or x8.5m, cover crop planting using Velvet bean (*Mucuna* sp.) (Figure 3A), heavy application of balanced fertilizers and mill biodegradable residuals like EFB & boiler ash, terracing, herbicide usage, pruning, circle weeding and regular harvesting. We noted that all the mentioned practices can be of advantage to intercropping as shown in the discussion section.

Projections on farmer gains or losses after implementing intercropping

Results in Figure 3A, on one hand show what farmers mentioned as the environmental, social and economic benefits of intercropping. While the majority of farmers were not aware of intercropping benefits, a reasonable number mentioned the importance of having their gardens free of unwanted weeds, as well as reducing soil erosion and enhancing environmental health due to having a diversity of plants. Key respondents mentioned the importance of having cover crops for the soil as a way of controlling soil erosion and that when the cover crops rot, they would increase soil humus. According to our personal experience, other advantages of intercropping include weed management, increasing biodiversity, availing habitat to birds and other beneficial organisms, as well as maintaining soil fertility.

Literature shows that intercropping with specific trees may increase carbon stock, decrease nitrogen leaching, decrease soil erosion (Khasanah et al., 2020), and it is advantageous because it involves minimal inputs which small scale farmers can afford. On the other hand, results in figure 3B generally show that 99% of farmers did not find any environmental cost of intercropping, 87% found no social cost coming with intercropping and 70% mentioned no economic cost of intercropping. However, outside of what the farmers said, respondents from OPUL mentioned some costs of intercropping including the reduction of oil palm yield if best agronomic practices like spacing are not carefully observed, and if intercropped with crops having aggressive root systems, there is competition for nutrients which does not favour yields. The competition related to spacing is confirmed by Chia (2011), Muryunika (2015) and Suboh et. al. (2009) although they are not explicit in the exact causes of yield depressions.

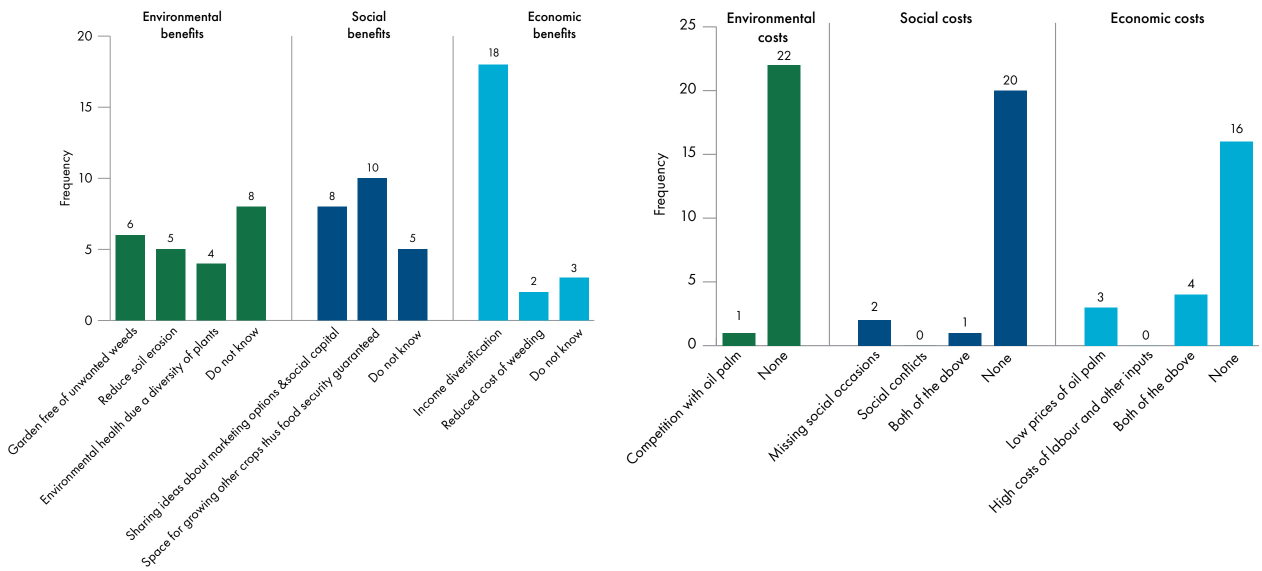

Figure 3. Frequency of responses on benefits and costs of intercropping

Projections on farmer gains/losses by implementing monocropping

While 12% of farmers mentioned that oil palm monocropping brought rain, 88% of farmers reported no environmental benefit of monocropping. However, 12%, 18% and 6% of respondents mentioned land conservation, infrastructure development and job creation respectively as some of social benefits that came with monocropping, whereas 67% of respondents saw no social benefit of monocropping.

Table 7. Environmental, social and economic benefits of monocropping

Benefits	Frequency
Environmental benefits:	
Some rain	2
No benefit	15
Social benefits:	
Land conservation	2
Infrastructure development	3
Job creation	1
None	11
Economic benefits:	
Encourages savings since it is little income	1
Expected monthly income	6
None	10

Economic benefits of monocropping were manifested by savings based on the little income, which was expected monthly, as respectively mentioned by 6% and 35% of farmers carrying out the monocropping option. For 59%of the respondents, monocropping had no economic benefit. Key respondents mentioned that farmers would economically benefit from monocropping through increased yield given that the monocrop consumes all nutrients without a competitor, hence an apparently better income for monocropping farmers (Table 8).

Table 8. Environmental, social and economic costs of monocropping

Costs	Frequency
Environmental costs	
Loss of tree biodiversity	5
Disruption of the rainfall system	3
Loss of soil quality and reduced land value	6
Do not know	3
Social costs	
No diversification of income generating activities	5
Disruption of social-cultural attachments due to loss of land ownership	7
Both of the above	2
Do not know	3
Economic costs	
Loss of income from trees	1
No income diversification	5
High transaction costs and farm maintenance	9
Do not know	2

Among the costs of monocropping, there was the loss of tree biodiversity, disruption of the rainfall system, loss of soil quality and reduced land value. Among those mentioned factors, loss of soil quality and reduced land value, as well as loss of tree biodiversity were mentioned as the most disturbing by respondents (Table 8). A few farmers did not know the environmental costs that came with monocropping. On the other hand, key respondents mentioned that during the process of land preparation, the top soil was exposed which led to erosion and loss of water in the soil. But monocropping may come with other environmental costs such as damage to human health due to pollution, depletion of natural capital, reduction in beneficial pollinators since monocultures depend on use of pesticides.

Regarding social issues, 53% respondents mentioned that monocropping had the cost of disrupting their social-cultural attachments since oil palm monoculture came with loss of land ownership and a tight schedule of working in the oil palm plantation. Another social cost was the inability to diversify income-generating activities. Three respondents did not know of any social cost attached to oil palm monocropping. From observations, monocropping of oil palm posed a danger of food insecurity because of loss of soil quality and less time spent to growing food crops.

Economically, oil palm monoculture came with high transaction costs, mentioned by 53% of respondents, no income diversification (29%), and loss of income from trees (6%). Furthermore, 12% did not know of any costs that came with monocropping, as key respondents did not mention any costs of monocropping.

Training received

Of respondents who had received training on intercropping, 9% received training on the method, stage and how to spray or manure their intercrops. We recorded that 71% of farmers carried out monocropping and received training on how to boost production; 17% on pests and diseases while 12% received training on the oil palm by-products.

Table 9. Farmers' mention of training

	On intercropping	On monocropping
Yes	6	17
No	17	0

It was reported by 26% of farmers that they received some training on intercropping while 74% mentioned having no training at all on intercropping. On the other hand, 100% of monocropping respondents mentioned having received training on the same.

Table 10. Types of training that farmers received

Subject	Training focus	Frequency
Intercropping	Method of intercropping	2
	Stage of intercropping	0
	How to spray and manure	0
	All the above	2
	None	19
Monocropping	How to boost production	12
	About by-product	2
	About pests and diseases	3

Inputs

Within the category of farmers practicing monocropping, fertilizers, labour, garden tools such as chisels, pangas, hoes, and land rent were mentioned as the inputs required. Among those mentioned, majority 59% of respondents mentioned fertilizers as the most needed input, followed by 41% respondents mentioning the need for all the mentioned inputs. Farmers carrying out intercropping mentioned only fertilizers and labour as needed inputs. All respondents practicing both intercropping and monocropping mentioned easy access to inputs, yet all of them mentioned their inability to afford the required inputs (Table 11).

Table 11. Farm input issues mentioned by farmers

	Type of input	No. mentioning inputs	No. able to access inputs	No. able to afford inputs
Monocropping	Land rent	0		0
	Fertilizers	10	10	0
	Tools	6	6	0
	Labour	4	4	0
	All the above	7	7	0
Intercropping	Fertilizers	11	11	0
	Labour	0	0	0
	Fertilizers and labour	10	10	0
	Land rent	1	1	0

Discussion

Results highlighted the factors that drive intercropping and monocropping farming systems, discussed here, leading to implications and conclusions on best ways forward. The study showed that more females were involved in intercropping than their male counterparts, and more monocropping farming systems were being run by males. This result makes a lot of sense since women are responsible for household food requirements and would therefore be more interested in having a variety of food crops than the oil palm cash crop. In studies on sustainable farming systems, women have been shown to participate more in activities that would bring a variety of food at home. For instance, in studies by ACALISE 2019, 46% of female farmers in Uganda practice intercropping as compared to 41% of males. Other scholars including Nchanji et. al. (2016) showed that intercropping is beneficial to women because the income obtained is normally used for general household upkeep and improved nutrition of the family. This implies that intercropping is taken as an improved agronomic practice. Since oil palm monoculture is a cash crop, it mostly attracts the attention of men and interests of men as seen from South East Asia where high productive profit maximizing monocultures dominate the landscapes (Corley and Tinker, 2003 in Teuscher et al., 2015). Furthermore, more farmers within the age of 30-55 practiced intercropping than monocropping. These were mostly female farmers.

Majority of farmers with land holdings of 1-4 hectares were in the category of "previously intercropped" while majority of farmers with 5- 8 hectares were in the category of "currently monocropping". Size of land is a likely major driving factor for intercropping systems especially with crops such as oil palms whose canopy cover can greatly affect other crops. Thus, farmers aspire to achieve a balanced diet and diversify sources of income, as such they are forced to have a multiplicity of crop commodities on their land and so the likely reason for intercropping.

As much as OPUL was not in support of intercropping, KOPGT mentioned the need for intercropping and gave reasons why farmers may intercrop for the first 1 to 3-4 years of oil palm growth. KOPGT is also under the Ministry of Agriculture, Animal Industry and Fisheries therefore their interest is not only in improving farmer incomes but also in sustainable food systems. Monocropping as found out is mostly emphasized by OPUL. As such, farmers' experiences in either intercropping or monocropping indicate that farmers carrying out intercropping have more years of experience than their counterparts practicing monocropping. It is logical since the monocropping system was just introduced to the Ssesse islands and farmers had been used to their traditional farming systems, with cultural practices which are common in especially Africa and America (Francis, 1986; Vandermeer, 1989; Li et al., 2013).

Beans, sweet potatoes and maize were the intercrops mentioned by farmers in our study areas. Of those, sweet potatoes were mentioned by the majority of farmers as the most common intercrops. We established that majority of farmers intercropped within the first three to four years since they were growing annual crops. These practices do not lead to yield penalties in intercrop whereas oil palm yield is not yet an issue. However, this may contribute little to a more heterogeneous structure which would benefit biodiversity (Phalan et al., 2009; Foster et al., 2011). Studies have shown that intercropping in oil palms can take place throughout the years of oil palm growth, depending on the type of crop grown and the planting densities and configurations, implying the importance of testing different crop combinations in experiments for the entire 25-year rotation of oil palm, as is done in the experiential learning model (Slingerland et al., 2019; Khasanah et al., 2020).

To maximize advantages of intercropping, farmers in new frontiers where oil palm farming systems are yet to be established could decide to include other crops such as black pepper, vanilla, cocoa, and teak (*Tectona grandis*) in their oil palm plantations. These crops can create permanent agroforests (Foster et al., 2011) as well as rewarding farmers with more diverse and perhaps even higher incomes at different moments in time. A consequence of such a choice is that planting densities of oil palm need to be much lower and that competition for light needs to be avoided else either oil palm yield (such as with teak) or intercrop yields (with cacao) will be much reduced. For example, studies have showed that black pepper does well with oil palm, can diversify farmer incomes and protect the environment, but only in double row avenue system (Slingerland et al.,2019; Yemadje et al., 2019). In addition, teak grows better as an intercrop with oil palm than in monocrop (Chia, 2011) but with a severe yield penalty in oil palm which will be felt every month whereas the benefit of the teak tree only comes once at felling. For such heavy competitors it is better to do block planting instead of mixed planting (Chia, 2011).

The growth of teak was observed in some gardens of oil palms in Uganda but some farmers were not aware of its importance in terms of future revenues nor aware of its potential competition with oil palm trees. No farmer in the Uganda case study was found to be intercropping black pepper with oil palm as it was not mentioned among intercrops in our study area. This implies the importance of having intercropping practices clearly understood and practiced in Uganda. We recommend shade tolerant crops such as cardamom, coffee and turmeric albeit with lower palm densities or double row avenue system as 4-5 years after planting oil palm trees will cast too much shade even for these crops.

Since the crops mostly grown are sweet potato, beans, cassava, maize, which are all annual crops, most farmers were seen to carry out intercropping within 3-4 years, commonly done in oil palm rows of 9x9m. The implication here is the need to educate farmers about other potential crops (e.g. black pepper, vanilla, cocoa, cardamom, coffee, turmeric and teak) that can survive longer in the oil palms but only when planting density and configuration of oil palm is adapted. People need to be well informed of potential oil palm yield penalties that need to be compensated for by the perceived or actual benefits of intercropping. And only when these potential crops are connected to markets, they can provide diverse income sources and products and help to off-set moments of temporary lower oil palm prices.

Similar to other intercropping systems elsewhere in Asia and Africa (Slingerland et al., 2019; Teuscher et al., 2015; Chia, 2011; Foster et al., 2011), farmers in our study areas were found to be intercropping immediately after planting the oil palms. Only 13% of intercropping farmers did it after a few months of planting oil palm. This is practical since oil palm can easily form canopy to suffocate other crops and this practice is in line with the farmers' mentioned need of sustainable land use, generating additional income for farmers (Knorzer et al., 2009; Martin-Guay et al., 2018; Omar et al., 2010).

As opposed to the intercropping farmers who carried out the practice to sustain land use, monocropping farmers did so mainly because the oil palm investor does not allow them to intercrop. For the company, oil palm is a cash crop and the company must meet market demand as much as possible. From observations in the field, farmers who practiced monocropping were not doing it because they desired but because it was not acceptable for them to intercrop like is the case in Asia where intercropping farmers were fined (Corley and Tinker, 2003; in Teuscher et al., 2015). One farmer said that "Oil palm company owners don't like intercropping because the intercrops consume some of the fertilizers meant for palm trees, thus affecting their yield...so they discourage us from intercropping."

Inclusive growth is probably something that we need to put at the fore front such that farmers are involved in undertaking agronomic practices that best suit their needs, including family food needs (Orewa, 2008). This implies that oil palm investment companies need to learn from farmers and be mindful of their family needs. That is why a majority of monocropping farmers saw no environmental, social and economic benefits of monocropping even though they were still stuck in the system.

Our results on the projections on what farmers may gain or lose by implementing the intercropping option showed that even though some farmers were not aware of the benefits of intercropping, a majority of them mentioned many benefits as seen in Table 7. This supports the benefits of intercropping (e.g. Orewa, 2008; Knorzer et al., 2009; Martin-Guay et al., 2018; Omar et al., 2010). Others (e.g. Nchanji et al., 2016) have shown how farmers in Cameroon found it more rewarding to intercrop than engaging in monocultures. In line with these studies and our on-the-ground study, results showed that intercropping has more benefits than costs and merits to be applied in new areas where oil palm is being extended in Uganda, as is indicated in our secondary data in Table 3.

In line with other studies, results in our study concretize the importance of intercropping for the small holder farmers and the need to educate or guide farmers on the best approaches to intercropping. In specific terms, the advantages of intercropping as mentioned by our respondents and literature (Francis, 1986; Knorzer et al. 2009; Omar et al., 2010; Martin-Guay et al., 2018; Meijaard et al., 2018; Slingerland et al., 2019; Khasanah et al., 2020) including sustainable land intensification, environmental health arising from, increasing biodiversity, availing habitat to birds and other beneficial organisms. Other benefits include weed management, diversifying farmer incomes, food security as well as maintaining soil fertility. As a follow-up on this study, there is need for a farmers' guide on intercropping systems. This farmers' guide is necessary because this research established that majority of respondents had not received any training on intercropping, yet all the interviewed monocropping farmers had received training on the same, especially on how to boost production/yield.

Note that yield is related to the amount of fertilizers applied to the farm. However, all respondents showed that even though fertilizers were easily accessible, they were also very expensive and thus not affordable. According to Lubke and Hildebradt (2019), use of synthetic fertilizers reduces soil life, and especially the effective role of humifying micro-organisms, hence preventing the breaking down of organic matter to form the crop required soil structure. This is evident from the hardened soils with lack of humus and formed loam soils, which explains rapidly declining performance of oil palm especially where deforestation took place. Our study established that oil palm smallholder farmers are forced by KOPGT to use fertilizers and on loan, and continuous dependence on synthetic fertilizers.

Conclusions and recommendations

From the literature review and field studies, results showed the advantages of intercropping in farmers' perceptions, and that it is a preferred farming system as a way to meet food requirements without depleting natural resources for a growing population as in Uganda (UBOS, 2018). Although most farmers were interested in intercropping, there were various limitations which undermined the extent to which it is being practiced in Kalangala district, in Bujjumba and Mugoye sub-counties and in the mainland.

Intercropping oil palm helps to overcome common agricultural challenges such as declining soil fertility, while providing alternative incomes and meeting food requirements. Crops such as banana, sweet potato, beans, cassava, maize, sugarcane and cocoyam do not compete with young oil palm in the first four to five years. Where permanent intercropping is concerned, crop combinations and adapted planting densities have been tested in other countries that minimise yield losses for oil palm and intercrops, or that compensate losses by higher total income per intercropped hectare than from monocropping.

For oil palm-cacao intercropping in a double row avenue system in Indonesia, the WaNulcas model estimated a land equivalent ratio (LER) of 1.4, i.e. that one ha intercropped generates as much income as 1.4 ha monoculture (Khasanah et al., 2020). Intercropping can thus lead to land saving and increased income per hectare. However, OPUL discourages intercropping to maximize company income gains from oil palm out-growers, though KOPGT acknowledges the importance of intercropping to smallholder farmers and encourages them to undertake the practice for up to 3-4 years, and as competition in the early years is very low, so oil palm companies have no reason to prevent this practice.

From the above conclusions, the following recommendations are drawn.

1. Promotion of intercropping instead of monocultures in new areas where oil palm is yet to be established would better fit farmer needs.
2. An integration of experiential learning, mapping of conservation areas and the double row avenue intercropping may be adopted to inform development of diverse oil palm growing systems in Uganda.
3. Crops such as yams, bananas, cassava, sweet potatoes, and beans can be promoted for intercropping on plantation establishment with no competition observed in the first 3-4 years.
4. Permanent intercropping with shade tolerant crops such as black pepper, white pepper, vanilla, cacao, coffee or turmeric require alternative oil palm planting spacing such as double row avenue (alley cropping) systems.
5. Promoting planting of timber trees in older oil palm fields (>8 YAP) may be compatible for some tree species (e.g. red meranti in Indonesia) whereas some timber species (e.g. jabon and magahony in Indonesia) already suffer when planted as border trees. However, no results are yet available from long term experiments.
6. Intercrops should preferably have good market prices so that they can make up for small oil palm yield penalties and can stabilize income next to fluctuating oil palm prices.
7. Smallholder farmers be educated on the intercropping farming system and best practices support to farmers who are practicing crop diversity.

References

ACALISE, 2019. *Report on agro-ecology and livelihood systems in Uganda: Refocusing attention on agro-ecology as a framework for mitigating climate change and food security to achieve sustainable development.* African Centre of Excellence for Agro-Ecology and Livelihood Systems (ACLISE), Kampala, Uganda.

Aidenvironment Asia, 2017. I*ntegrating oil palm into the landscape. Initial lessons learnt from the field.* Aidenvironment Asia, 15pp.

Ashraf M, Zulkifli R, Sanusi R, Tohiran KA, Terhem R, Moslim R, Norhisham AR, Ashton-Butt A, Azhar B, 2018. Alleycropping system can boost arthropod biodiversity and ecosystem functions in oil palm plantations. *Agriculture, Ecosystems and Environment*, 260:19-26.

Biggam J, 2008. *Succeeding with your master's dissertation: A step-by-step hand book.* Open University Press, UK.

Chia FR, 2011. Survival and growth performance of teak under monocrop system and intercropped with oil palm. S*epilok Bulletin*, 13/14:33-42.

de Vos RE, 2016. Multi-functional lands facing oil palm monocultures: A case study of a land conflict in West Kalimantan, Indonesia. *ASEAS-Österreichische Zeitschrift für Südostasienwissenschaften*, 9(1):11-13.

Erhabor JO, Filson GC, 1999. Soil fertility changes under an oil palm-based intercropping system. *Journal of Sustainable Agriculture*, 14:45-61.

FAO. 2013. *Advancing agroforestry on the policy agenda: A guide for decision-makers.* By Buttoud G, in collaboration with Ajayi O, Detlefsen G, Place F, Torquebiau E. Agroforestry Working Paper No. 1. FAO, Rome, Italy. 37pp.

FOE, 2012.*Land, life and justice: How land grabbing in Uganda is affecting the environment, livelihoods and food sovereignty of communities.* Friends of the Earth International, 20pp.

Foster WA, Snaddon JL, Turner EC, Fayle TM, Cockerill TD, Ellwood MDF, Broad GR, Chung AYC, Eggleton P, Khen CV, Yusah KM, 2011. Establishing the evidence base for maintaining biodiversity and ecosystem function in the oil palm landscapes of South East Asia. Philos. *Trans. R. Soc. Biol. Sci.*, 366, 3277-3291.

Francis CA, 1986. *Multiple Cropping Systems.* Macmillan Publishing Company, New York, USA.

Gonclaves A, Hook K, Moberg F, 2017. *Applying resilience in practice for more sustainable agriculture.* Policy Brief. Swedish Society for Nature Conservation, Stockholm, Sweden, 27pp.

Khasanah N, van Noordwijk M, Slingerland M, Sofiyudin M, Stomph D, Migeon AF, Hairiah K, 2020.Oil palm agroforestry can achieve economic and environmental gains as indicated by multifunctional land equivalent ratios. *Frontiers in Sustainable Food Systems*, doi: 10.3389/fsufs.2019.00122

Knörzer H, Graeff-Hönninger S, Guo B, Wang P, Claupein W, 2009. The rediscovery of intercropping in china: a traditional cropping system for future Chinese agriculture – A review. In: Lichtfouse E (ed). Climate Change, Intercropping, Pest Control and Beneficial Microorganisms. *Sustainable Agriculture Reviews*, Vol 2. Springer, Dordrecht, the Netherlands.

Kolb DA, 1984. *Experiential Learning: Experience as the source of learning and development.* Prentice Hall, New Jersey USA.

Lal R, Ghuman BS, Shearer W, 1992. Cropping systems effects of a newly cleared ultisol in southern Nigeria. *Soil Technology*, 5:27-38.

Laeshe CH, 1975. A quantitative approach to content validity. *Personnel Psychology*, 28:563-575.

Li L, Zhang L, Zhang F, 2013. *Crop mixtures and the mechanisms of overyielding.* In: Levin S (ed), Encyclopedia of Biodiversity.Waltham Academic Press. pp382-395.

Lubke A, Lubke S, Lubke U, Hildebrandt U, 2019.*Humus management and composting.* Seminar and Training programmes, Landmanagement: United Research for Soil, Puerbach, Austria. 191pp.

Martin-Guay M-O, Paquette A, Dupras J, Rivest D, 2018. The new green revolution: sustainable intensification of agriculture by intercropping. *Science of the Total Environment*, 615:767-772.

Meijaard E, Garcia-Ulloa J, Sheil D, Wich SA, Carlson KM, Juffe-Bignoli D, Brooks TM (eds), 2018. *Oil palm and biodiversity. A situation analysis by the IUCN Oil Palm Task Force.* IUCN Oil Palm Task Force, IUCN, Gland, Switzerland, 116pp.

Muryunika R, 2015. *Strategi pengelolaandan pengembangan agroforestri berbasis kelapa sawit di jambi.* MSc thesis, University of Bogor, Indonesia.

Namanji S, Ssekyewa C, 2018. *Mitigating negative impacts of oil palm expansion in Kalangala, and complementary livelihoods options.* In: Ssemenada R, Opige MO (eds), Oil palm plantations in forest landscapes: impacts, aspirations and ways forward in Uganda. Tropenbos International, Wageningen, the Netherlands. pp47-50.

Nchanji YK, Nkongho RN, Mala WA, Levang P, 2016. Efficacy of oil palm intercropping by smallholders. Case study in South-West Cameroon. Agroforestry Systems, 90:509-519.

Nuertey BN, 1999. *Studies on oil palm based cropping systems in Ghana.* PhD thesis, University of Ghana, Accra, Ghana.

Ofo MC, Lucas EO, 1988. *The performance of oil palm (Elaeis guineensis Jacq.) and some food crops under intercrop system and the effects on soil factors in cassava-based cropping systems research.* IITA, Ibadan, Nigeria, pp57-67.

Okpala. A, 1995. Resources, environment and economic development in Nigeria. *J. Dev. Soc.*, 11:151-158.

Omar RZR, Omar W, Khasim N, 2010.*Sweet potato production in oil palm plantations. Malaysian Palm Oil Board*. Ministry of Plantation Industries and Commodities, Kuala Lumpar, Malaysia.
Onwubuya II, Eneh FK, 1987. *Testing the feasibility of associating cassava and other food crops in oil palm intercropping systems*. Paper presented at the Annual Meeting of the Cassava Based-Cropping Systems Research Network, 16-19 November 1987, IITA, Ibadan, Nigeria.
Orewa SI, 2008. Designing agricultural development projects for the small scale farmers: Some lessons from the world bank assistance small-holder oil palm development scheme in Nigeria. *Journal of Applied Sciences*, 8(2): 295-301.
Phalan B, Fitzherbert EB, Raffegeau S, Struebig MJ, Verwilghen A, 2009. Conservation in oil-palm landscapes. *Conservation Biology*, 23:244-245.
Government of Uganda, 2015. *Frontiers in Rep. of Uganda. Constitution of the Republic of Uganda*. Uganda Printing and Publishing Corporation, Entebbe, Uganda. 260pp.
Ruysschaert D, Darsoyo A, Rizwan Z, Singleton I, 2011. *Developing palm oil production on degraded land: Technical, economic, biodiversity, climate, legal and policy implications*. Pan Eco, Yayasan Ekosistem Lestari (YEL) and ICRAF.
Salako E, Lal R, Swift M, 1995. Intercropping oil palm (*Elaeis guineensis*) with cocoyam (*Xanthosoma saggitifolium*) on windrows and non-windrows in southern Nigeria. *Journal of Sustainable Agriculture*, 6:47-60.
Sanjeevraddi R, Patil DR, Chandravathi B, Maheswarappa HP, 2015. Studies on vegetables as intercrops in juvenile oil palm plantation and its economics. *Karnataka Journal of Agricultural Sciences*, 28(4):494-496.
Slingerland M, Khasanah N, van Noordwijk M, Susanti A, Meilantina M, 2019. Improving smallholder inclusivity through integration of oil palm with crops. *ETFRN News*, 59:147-154. Tropenbos International, Wageningen, the Netherlands.
Sparnaaij LD, 1957.Mixed cropping in oil palm cultivation in West Africa. *Inst. Oil Palm Report*, 1(7):244-264.
Ssemmanda R, Opige MO (eds), 2018. *Oil palm plantations in forest landscapes: impacts, aspirations and ways forward in Uganda*. Tropenbos International, Wageningen, the Netherlands. 55pp.
Ssemmanda R, Opige MO (eds), 2019. *An assessment of the impacts of oil palm in Kalangala and Buvuma. Lessons learned and recommendations for future developments*. Tropenbos International, Wageningen, the Netherlands. 81pp.
Straub D, Boudreau MC, Gefen D, 2004. Validation guidelines for IS positivist research. *Communications of the Association for Information Systems*, 13:380-427.
Suboh I, Norkaspi K, Zulfkifli RO, 2009. Double-row avenue system for crop integration with oil palm. *MPOB Information Series* No. 465.
Taherdoost H, 2016. Validity and reliability of the research instrument: How to test the validation of a questionnaire/survey in a research. *International Journal of Academic Research in Management*, 5(3):28-36.
Teuscher M, Vorlaufer M, Wollni M, Brose U, Mulyani Y, Clough Y, 2015. Trade-offs between bird diversity and abundance, yields and revenue in smallholder oil palm plantations in Sumatra, Indonesia. *Biological Conservation*, 186:306-318.
Tropenbos International, 2018. *New insights into oil palm impacts through role playing*. Infobrief. Tropenbos International, Wageningen, the Netherlands. 2pp.
Trostle R, 2008. *Global agricultural supply and demand: factors contributing to the recent increase in food commodity prices*. USDA, Washington DC, USA.
UBC, 2019. 10pm News, Uganda Broadcasting Corporation.
UBOS, 2018. *Statistical abstracts*.Uganda Bureau of Statistics, Kampala, Uganda, 341pp.
Vandermeer JH, 1989. *The Ecology of Intercropping*. Cambridge University Press, UK.
van Noordwijk M, Lusiana B, Khasanah N, Mulia R, 2011. *WaNulCAS Version 4.0. Background on a model of water nutrient and light capture in agroforestry systems*. ICRAF, Bogor, Indonesia. 224pp.
Yemadjea RH, Cranec TA, Vissohb PV, Mongbo RL, Richards P, Kossoub DK, Kuyper TW, 2012. The political ecology of land management in the oil palm based cropping system on the Adja plateau in Benin. NJAS - *Wageningen Journal of Life Sciences*, 60/63:91-99.

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