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Cover Crops Implementation in Mango and Longan Orchards in Battambang Province, Cambodia

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ABSTRACT: After years of mono-cropping and farmland expansion, Cambodia faces soil degradation, deforestation, and biodiversity loss. Conservation Agriculture (CA) could improve the Cambodian situation. Among the CA approaches, permanent soil organic cover, like cover crops, decreases soil erosion, suppresses pests and diseases, and increases yields. Currently, in Cambodia, CA practices are mainly implemented in cash crops, such as soybean, corn and cassava, leaving marginal-income crops, such as fruit trees, behind. More research about CA in fruit tree production in Cambodia is needed. This study investigates cover crops' opportunities and constraints in mango and longan orchards and farmers' knowledge and attitude towards this practice. Mango and longan are a source of subsistence income in the country and, therefore, do generally receive less focus. Qualitative and quantitative data collection was conducted in 2022 in Battambang province. Thirty-nine semi-structured household interviews were led in nine villages of Rattanak Mondoul and Banan districts, with CA-, CT- (conventional) and CT (CA*)- (previous CA, now CT) farmers. Two Focus Group Discussions (FGDs) were led in the Sangha and Borun villages of Rattanak Mondoul districts. Key informant interviews and a literature review were used to gather data. The results showed that most farmers do not know the definition of CA. CA- and CT (CA*)-farmers are satisfied with applying cover crops and recommend CT farmers to grow them. CT farmers are willing to start growing cover crops in their orchards. The main reasons for farmers to start growing cover crops are weed presence, low soil fertility and high erosion in the orchards. Farmers have noticed an improvement in their orchards and fruit yield since they started growing cover crops. Farmers believe more training and technical support about CA and covering crops are needed. This might also attract more farmers to these approaches, increasing the adoption of CA techniques, improving Cambodian agriculture and reducing soil degradation, deforestation and biodiversity loss.

Keywords: Cambodia, Conservation Agriculture, cover crops, farmers' adoption.

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INTRODUCTION

Between the late 1990s and early 2000s, a flow of in-migration towards the rural zones of Cambodia was observed, especially in Battambang and Pailin provinces. (Boulakia et al., 2013). Entire households moved to purchase rural land. Hectares of dense and thick forest were cleared and converted into agricultural land. (Boulakia et al., 2013). Monocropping systems

substituted traditional and diversified cropping systems for commercial crops, such as maize and cassava. (Kong et al., 2021). Besides, the intensive chemical and mechanical weed control and the use of chemical fertilizer, combined with years of monocropping, led to a decrease in cassava yields, the main crop cultivated in the area (Boulakia et al., 2013). The farmland expansion and the shifting to monoculture systems contributed to the acceleration of deforestation, the depletion of soil fertility, the loss of biodiversity and the pollution from the increased use of chemical inputs. (Kong et al., 2021; The World Bank, 2015).

The districts of Rattanak Mondoul and Samlout are located in upland areas of Battambang province. Vernet et al. (2020) This indicates that an agrarian transition began in 1998 and went through three stages. In the first stage, 1998-2004, subsistence farmers cultivated soybeans, peanuts, and sesame as cash crops. The second stage, until 2014, saw the cultivation of maise and cassava, where smallholder farmers' conditions improved dramatically. However, soil fertility and crop productivity declined. Starting in 2014, the third stage saw some farmers transition into growing fruit orchards, mainly mango and longan. (Vernet et al., 2020). Implementing cover crops in the fruit tree sector in Cambodia is still an emerging concept. This study investigates cover crops' opportunities and constraints and fruit tree producers' knowledge and attitude towards this approach in the upland area of Battambang Province. The study explores the level of farmers' knowledge and attitude towards cover crops in the fruit tree sector, probes the reasons farmers apply cover crops in the fruit tree sector, and examines the opportunities and constraints of cover crops on their farms. Finally, the study looks at what is needed to expand cover crop implementation from a farmers' perspective.

Conservation Agriculture (CA) is one of the approaches that help reduce land degradation and optimise on-farm resources' use (SoCo, 2009, p. 200). CA has three principles: minimal mechanical soil disturbance (no tillage), permanent soil organic cover, and species diversification and crop rotation (Kienzle & Njenga, 2016). Minimum soil disturbance improves soil properties and preserves and increases soil organic matter, reducing soil erosion (Climate ADAPT, 2019). The latter is simultaneously reduced by cover crops and crop residues, which enable climate change adaptation, improve soil fertility and increase biodiversity (Climate ADAPT, 2019). Crop diversification and crop rotation, among other practices, interrupt the disease cycle, reduce the number of weeds, and promote the interaction of beneficial soil bacteria (Barman et al., 2022). CA in Southeast Asia (SEA) was adopted two decades ago (Legoupil et al., 2015). In Cambodia, CA studies were mainly focused on maize, soybean and cassava associated with stylo legume (*Stylosanthes guianensis*) and other cover crops (Legoupil et al., 2015).

Cover crops can have several benefits, such as the promotion of pest suppression, the reduction of soil erosion, and the increase of the yield of the main crop. (Snapp et al., 2005), the N fixation of legumes (Fageria et al., 2005), the high nutrient supply in the soil that leads to a reduction of fertilizer inputs decreasing, in turn, fertilizer costs (Lehmann et al., 2000). To confirm this, a study conducted by Dinesh et al. (2004) on leguminous cover crops in humid tropics, which found that repeatedly in situ incorporation of cover crops can lead to the long-term sustainability of soil fertility. In addition, covering crops controls weeds through competition, reducing herbicide use and lowering production costs. (Snapp et al., 2005). Cover crops can also have costs. An opportunity cost can be associated with cash crops: the income from cash crops can sometimes be exceptionally low. The adoption of cover crops growing in the same period and in the same space as cash crops can be discouraged and sometimes avoided because of competing with the main cultivated crops. (Snapp et al., 2005). Nevertheless, in orchards, cover crops are no longer seen as competition but as a resource to increase biodiversity. (Giacalone et al., 2021).

Studies about the effect of cover crops on soil microbial communities and functions in mango orchards were led in China between 2017 and 2019. Wei et al. (2021) found that *Brachiaria eruciformis* (grass) and Butterfly pea (*Clitoria ternatea*) (legume) have a higher impact on the mango yield and a better fruit quality than Stylo legume (*Stylosanthes guianensis*) (legume). Meanwhile, in Brazil, Ferreira Dias et al. (2020) concluded that treatments with cover crops

between lines of mango trees, independently of the type of mix (75% leguminous + 25% non-leguminous or conversely) or the soil management (tillage or no-tillage), achieved better and long-term performances than treatments with spontaneous vegetation. After banana, mango (*Mangifera indica*) is Cambodia's second most produced fruit crop (Roberts et al., 2019, p. 2). Its cultivation area expands to over 100,000 ha in Kampong Speu, Battambang, Kampot and Banteay Meanchey provinces (Hin, 2019). In 2019, Cambodian mango production reached 72.53k Mt, and imported mango was 167 Mt (Won, 2021). Cambodia plays a minor role in the mango export market worldwide, as it ranks 39th among mango-producing countries (Won, 2021). Most of the exported produce goes to Vietnam, Thailand and Singapore at low prices controlled by the importers (Roberts et al., 2019; Won, 2021). Due to its weak export power, the increased production in the country and the impacts of the pandemic of COVID-19, the domestic market suffered from the excess supply, particularly during pick season, dropping the prices from 850 Riel (about USD 0.20) per kg to 350 Riel (about USD 0.08) in 2020 in very short time, during the COVID-19 era, marked by lockdowns, processing factory closures, and transportation restrictions across districts, the ecosystem suffered from lost revenue. For smallholder farmers, lost revenue has immediate repercussions that can result in a lack of ability or incentive to continue producing mangoes (Evans, 2022).

Longan (*Dimocarpus longan*) is mostly cultivated in the provinces of Pailin, Battambang and parts of Preah Vihear provinces (Thou, 2021). The total area dedicated to longan production in Cambodia is 13,608 ha (Hom, 2022). The most known variety is Pailin Longan, named after the province. It is usually sold domestically or in Thailand. (Hom, 2022). In 2020, the price of 1 kg longan on the international market was 4,000 Cambodian Riel (~USD 1.00), while in the domestic market, 2,500 Cambodian Riel (~USD 0.625) (Schall, 2020).

METHOD

Site description

The data collection for this study covers primary and secondary data. Primary data collection consists of semi-structured household interviews led from May to July 2022 in nine villages of Rattanak Mondoul and Banan districts of Battambang province, Cambodia (Fig. 1). The nine villages are Bourn Chour, Onderk 11, Ou Lamoun, Neang Lem, Ou Khmom, Sangha, Sdau, Borun, Ta Krork. Focus Group Discussions (FGDs) were led in August and September 2022 in Borun and Sangha villages in Rattanak Mondoul district. Key informant interviews were used to complete the primary data collection. The site was chosen for a main reason: the project is implemented by the ISA (Innovation for Sustainable Agriculture) team, by the NGO Swisscontact, which works in Battambang province, and with the help of CASC (Conservation Agriculture Service Center), a unit of the Department of Agricultural Land Resources Management (DALRM, GDA), who promotes ecological intensification of the cropping systems to increase the profitability of small-scale farms, who works in five provinces, including Battambang province, in Rattanak Mondoul district. The number and kinds of villages selected depend on the origin of the farmers interviewed.

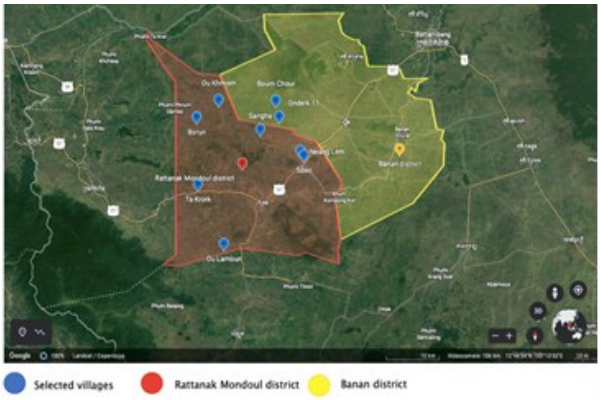

Figure 4. The research site of the study in Battambang province

Cambodia's climate is classified as Aw (Tropical wet-dry climate) according to the Köppen-Geiger climate classification. (Arnfield, 2022). The country has two seasons: a dry season, from November until May, and a rainy season from June to October. (CountryReports, no date b). Based on 29 years of data (between 1991 and 2020), the average annual rainfall is 1832.54 mm, between 1,400 and 2,000 mm. (Climate Change Knowledge Portal, no date). The primary data

was collected at an elevation between 10 and 350 asl. (Google Earth, 2022).

Communities selected

The sample was chosen through purposive sampling. The criteria for choosing the sample were two: first, the farmers must grow either mango or longan or both; second, the growing area of these two crops must be at least 1 ha. The snowball sampling method was used to complete the data collection of the semi-structured household interviews. Village chiefs, farmers, and researchers were asked to recommend available farmers for interviews. The snowball sampling method could generate sampling bias, but during this research, the sampling criteria were always considered to select farmers, mitigating biases. Farmers implementing cover crops, called CA farmers, and conventional (CT) farmers were interviewed. In addition, previous CA farmers who stopped growing cover crops temporarily were interviewed and called CT (CA*)-farmers. In total, 14 CA farmers, 21 CT farmers and four CT (CA*)-farmers were interviewed. CASC provided two lists with farmers' generalities and phone numbers to allow the contact for the semi-structured interviews. The data collection stopped when the number of CA and CT (CA*)-farmers together and CT farmers were almost even so that the data could be as valid as possible. Another reason for reaching the sampling size of 39 is that no more farmers with the sampling criteria could be found in the selected site.

The sample included 15 female and 26 male farmers (two interviews were conducted with husband and wife together). The average age of the interviewees is 50 years, ranging between 21 and 81 years. The average cultivated surface is 18.93 ha, between 1.7 and 100 ha. All of the farmers interviewed owned farms but still rented some land. They cultivate perennial crops on owned land and annual crops on rented land. Maize and cassava intercropped with mango are widespread. Out of 39 sample farmers, eight grow mango, 10 grow longan, and 21 grow both.

Table 1. Number of interviewees separated by gender and farming technique

Gender	Number of CA- farmers	Number of CT (CA*)-farmers	Number of CT-farmers	Total
Women	5	2	6	**13**
Men	8	2	14	**24**
Husband and wife	1	0	1	**2**
Total	**14**	**4**	**21**	**39**

Two FGDs were led in Borun and Sangha villages, where the same farmers from the semi-structured household interviews from these villages were invited. Eight farmers from Borun village were invited, and five attended, not all from the invitation list. Nine farmers from Sangha village were invited, and seven attended. Village chiefs had the task of inviting farmers from a list to attend the FGD, but not all of them were contacted and consequently did not attend.

Key informant interviews completed the data collection. The study is part of the ISA project, implemented by the Swiss NGO Swisscontact. The ISA team provided knowledge about the project and the roles of the different stakeholders. CASC was an important source of information about the research site and the sample. A general overview of the Rattanak Mondoul and Banan districts and the farmers living and working in these regions was collected thanks to CASC. CIRAD (Centre de coopération internationale en recherche agronomique pour le développement) is a French agricultural research centre for development and it works in collaboration with CASC to provide technical and scientific support about CA-based cropping systems. Its researchers were a precious source of information about CA and its current situation in Cambodia.

Details of the questionnaire

The 39 semi-structured household interviews were led face-to-face at farmers' houses or on the field. The semi-structured interviews included five main topics: general information about the interviewee, the growing of

mango and/or longan trees, conservation agriculture, opportunities and constraints of cover crops, and selling activities. Two questionnaires, one for CA- and one for CT farmers, were created. The questions were the same for CT and CA farmers, except for the conservation agriculture part, whereas the questions were more precise for CA farmers. The surveys consisted of simple, closed questions and open-ended questions. After the interviews lasted no more than one hour, transect walks communications in the orchards and observations were conducted.

During the FGDs, three questions were discussed: i) Which constraints in mango and longan orchards should the cover crop prevent/solve? ii) What should the cover crop be used for?; iii) How should the project make cover crop seeds accessible for everybody? For the first question, farmers were presented with ten cards with one constraint on each card that could appear in their orchards. In addition, they were given ten stickers with numbers from one to ten. They had to put the sticker number one on the most important constraint in their orchards, number two on the second most important, and so on. At the end of the exercise, the numbers on the cards were summed up, and the constraints were put in order from the most to the least important. A discussion about farmers' constraints and their expectations from cover crops was led. The second and third questions treated during the FGDs were asked directly to each farmer, and their answers were tracked. A discussion about their point of view followed.

Key informant interviews were led face-to-face, during transect walks on the field, and online from Cambodia and Switzerland.

Secondary data source

The secondary data collection began before the primary data collection, continued throughout the research period, and was finalized after the data analysis. The secondary data collection consists of a literature review. Information about the context of Cambodia, CA cover crops' benefits and costs, and mango and longan production in Cambodia was searched. Websites such as Google Scholar, Web of Science, Swisscontact.com and several keywords, such as Conservation Agriculture, cover crops in the fruit tree sector, crop diversity, mango and longan production in Cambodia were used—the program Zotero was used to collect and cite the sources.

Data analysis

Most of the household interviews and focus group discussion data were qualitative. The answers to the multiple-choice questions in the semi-structured interviews were "quantified" to simplify the analysis. For every point the farmers would mention, it would be given 1, meaning "yes", or 0, meaning "no", to each answer. This method allows the number of answers to be added and easily analysed. Microsoft Excel was used as an analysis tool for the quantitative and "quantified" qualitative data.

The open questions of the surveys were transcribed and coded in NVivo. This operation allowed us to gather many answers and analyse them separately. The FGDs were transcribed and analysed with NVivo as well.

RESULTS

Farmers' knowledge towards cover crops

The first research question is "What are farmers' knowledge and attitude towards cover crops in the fruit tree sector?". During the semi-structured household interviews, farmers were asked to define CA in their own words (Fig. 2).

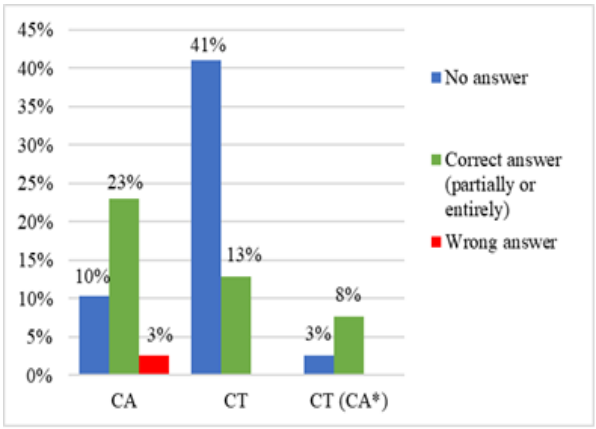

Figure 5: Percentage of correct, wrong and no answers separated by farming technique CA, CT and CT (CA*), (n=39)

Nine out of 14 CA farmers, five CT farmers and one CT (CA*)-farmer know partially or entirely the definition of conservation agriculture. The most mentioned definitions were "soil fertility improvement", "to grow cover crops, soil covered", and "protection from soil

erosion". One CA farmer gave a wrong definition of CA. Meanwhile, four CA farmers, 16 CT farmers, and three CT (CA*) farmers admitted that they did not know the definition of CA.

Farmers' attitude towards cover crops

Fourteen CA- and four CT (CA*)-farmers were asked to give a mark between one and ten, where one means "not satisfied at all" and ten means "completely satisfied", about their satisfaction with cover crops. All 18 farmers answered with a mark superior or equal to five (Fig. 3). The average mark is 7.72, and the mode is 8. The reasons for such high marks are fewer weeds in the orchards, improved soil fertility, less soil erosion, and the function of covering crops as a natural fertilizer.

CA- and CT (CA*)-farmers were asked if they would recommend cover crops to CT farmers. Twelve out of 18 would recommend other farmers to grow cover crops; two CA farmers would wait before recommending it, and two CT (CA*)-farmers would not. The most mentioned reasons for recommending it are improving soil fertility and decreasing soil erosion, higher yields and decreased weed presence, less or no-till and fewer chemical fertilizers used. Two farmers would wait before being recommended to grow cover crops because they had not seen their impact yet. Two farmers would not recommend it because, in one case, one farmer is not clear about what cover crops are and how they work yet, and in another case, a farmer claims that cover crops do not make you earn money.

Thirteen out of 21 CT farmers are willing to start growing cover crops. The main reasons are to improve soil fertility, to control weeds, and to decrease soil erosion and pesticide costs. Three CT farmers would like to be informed more about cover crops and their benefits through CASC's training before growing them. Meanwhile, five CT farmers are unwilling to start growing cover crops because of a lack of space in the orchards, lack of land, and preference to grow other, more profitable crops such as grass for livestock.

Table 2. CA- and CT (CA*)-farmers' satisfaction rate of cover crops, (n=18)

Grade/ Respondents	CA	CT (CA*)	Average grade (Grade * #answers)/Total answers)
5	4	0	20
6	1	0	6
7	0	1	7
8	5	1	48
9	1	1	18
10	3	1	40
Total	14	4	7.72

Farmers' reasons for applying cover crops in mango and longan orchards

CA- and CT (CA*)-farmers were asked what factors convinced them to start growing cover crops. The most mentioned reason with 15 answers is to control weeds in the orchards, improve soil fertility, and decrease soil erosion with 13 and 11 answers, respectively. Other reasons were to increase the yields, save more water in the soil, decrease production costs, convert to no-till, and increase water infiltration. Nobody from the 18 CA- and CT (CA*)-farmers started growing cover crops because of pests and disease problems. In all interviewed villages, soil infertility was a concern. Farmers in Sangha and Borun villages highlighted the challenges of soil erosion.

CT (CA*)-Farmers were asked what the reasons for stopping the growth of cover crops were. All four stopped for different reasons but claimed this break was temporary and would start growing cover crops again. In two cases, the

cover crop was not correctly handled, or the lack of light in the orchard did not allow for good growing, which later died. Technical support is needed in these cases to allow farmers to profit from cover crops. In another case, the farmer's husband's sickness impedes her from properly caring for the cover crop because of a lack of time. In the last case, the cover crop was cultivated for seed production. During the season, bad weather causes bad seed quality. The costs exceeded the income, and the farmer stopped.

CT farmers were asked why they had not started growing cover crops yet, and their answers can be divided into "lack of awareness/knowledge" and "lack of interest/income". The main reason mentioned is the lack of knowledge about CA and cover crops and, in some cases, also because they never heard about it. Other reasons are the lack of space under the trees that does not allow the passing through of machines or the presence of sunlight necessary for growing cover crops. Technical support is needed to manage better the orchards and the subsequent efficient growing of cover crops. Some farmers still lack interest in CA and covering crops. They prefer to grow more profitable crops, like maize, cassava and grass for livestock. Some are also held back because of a lack of CA farmers in the village, and they do not want to risk being the first implementers.

Opportunities of cover crops in mango and longan orchards

One of the opportunities for cover crops is that they can be used for different purposes. Eighteen CA- and CT (CA*)-farmers from Rattanak Mondoul and Banan districts grow sunn hemp, *Arachis repens*, *Arachis pintoi* (pinto peanut) or peanut (*Arachis hypogaea)* in their mango and/or longan orchards (Fig. 4).

Figure 4. (from left above): sunn hemp, Arachis repens, beans, Arachis pintoi (Source: Marcon 2022)

All of them are used to improve soil fertility, decrease soil erosion, suppress weeds, and act as a natural fertilizer. Sunn hemp is an annual cover crop, rotated with maize and cassava in mango orchards. It is used in six cases only to be left on the soil as a natural fertilizer and in two cases to sell its seeds. *A. repens* is a living, perennial cover crop, grown mainly in longan orchards where it stays low on the ground. It is cultivated by seven farmers and used to be left on the soil as a natural fertilizer and soil fertility improver. *A. pintoi* is similar to *A. repens* but less spread. In one case, it is also used as fodder for animals. *A. hypogaea* is used to sell, to be left on the soil and as food for human consumption. Figure 5 summarizes the uses of each cover crop type and the frequency of answers.

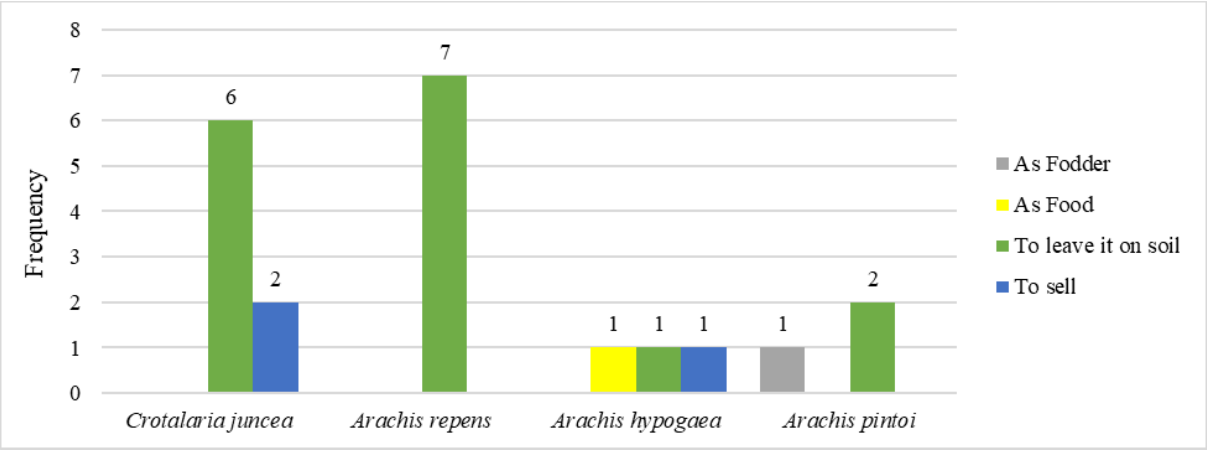

Figure 5. Cover crop types and uses, and frequency of answers given for each use, (n=18).

To understand the other benefits of covering crops, farmers will be asked which improvements they observed in their orchards after implementing them. The kind of answers can be divided into three main groups: soil health, plant health, and agro-economic answers (Fig. 6). Plant health constitutes 45% of the answers and includes less soil erosion (15 answers), improved soil fertility (eight answers) and increased presence of earthworms in the soil (two answers), among others. Plant health constitutes 36% of the answers and includes fewer weeds (15 answers), higher conservation of water (four answers), fewer pests and diseases (two answers) and sound growth of the plants (two answers). Agro-economic answers constitute 19% of the total answers and include higher yields (nine answers), less production costs (two answers) and higher income (one answer). In addition, all 18 CA- and CT (CA*)-farmers declare that their production costs decreased in labour, fertilizer, pesticides, machinery and irrigation.

Constraints of cover crops in mango and longan orchards

Cover crops also have constraints. CA- and CT (CA*)-farmers were asked which constraints they have seen in cover crops since growing them in the orchards. Eight out of 18 declared that they never had problems with cover crops. Five farmers declared having problems with pests that they control with insecticides. Two farmers complained that it takes time for living cover crops to grow. The only solution is to have patience and wait. CT farmers were also asked to present the challenges they face in their orchards without cover crops. Fifteen farmers were declared to have pests and diseases, and thirteen had many weeds. They are fought chemically with insecticides and herbicides and mechanically for weed control. Soil erosion and soil infertility are also present. In the case of soil erosion, farmers do not do anything; meanwhile, in the case of soil infertility, they apply organic fertilizer. Some common points and divergences emerged during the FGDs in Borun and Sangha villages. Both villages have soil fertility problems. Farmers respond to this problem by stopping to plough and growing cover crops. Soil dryness is another important constraint in both villages: after heavy rainfalls, the soil erodes and becomes dry and hard. Farmers claimed that by growing cover crops, they observed less soil dryness because the crops could maintain the moisture in the ground. The constraint of soil erosion is directly linked to soil dryness and infertility. When the soil rich in nutrients is washed away, the soil becomes infertile and dry. Pests and diseases are more of a problem in Borun than in Sangha village. Farmers fight them by spraying insecticides but want to shift to a more ecological and biological solution. Using chemical fertiliser seems more of a concern in Sangha village, where farmers claim it could help in the short term, but it decreases soil fertility in the long term and increases costs.

Cover crops' use expansion from farmers' perspective

CA- and CT (CA*)-farmers were asked during the semi-structured household interviews and the FGDs what the project should do to extend the use of cover crops to a wider farmers group. Most interviewees said more training about CA and cover crops is needed. CASC

should provide more training per year and technical support to CA farmers to improve the quality of cover crops and allow farmers to profit from them entirely. Nine out of 18 farmers said that giving machinery and seeds for free could attract more farmers. Other farmers suggested giving CA farmers a chance to show their cover crop field to CT farmers during workshops or training. Their intervention and personal experience could convince CT farmers to convert to CA. Other suggestions were mentioned during the FGDs. Farmers suggested that the project cover 50% of the cover crop seeds price to allow poorer farmers to adopt CA. Others suggested the project to give them credit: they would receive cover crop seeds for free at the beginning of the season and pay for them after the harvest.

DISCUSSION

Farmers' knowledge and attitude towards cover crops

Almost 44% of the interviewees know the meaning of CA, even those who do not implement it. The credit for this rate can be given to CASC, which has presented and still does cover crops and CA techniques in Battambang province. For those farmers who still do not know the definition of CA, informative days and field visits can be proposed by CASC or village organizations. The most competent CA farmers could also present themselves as CA to CT farmers and their experience with cover crops, such as their satisfaction rate. All CA- and CT (CA*)-farmers gave a mark equal to or superior to five when rating their satisfaction with cover crops. It shows that farmers are satisfied overall and that cover crops can meet their expectations if grown correctly. Both genders, women and men, are very satisfied with cover crops. This is a positive result for the project and CASC. Farmers from the Sangha and Borun villages were more satisfied than those from the other villages interviewed. Also, farmers growing cover crops for a longer time gave a higher mark. This phenomenon can be explained by the focus of CASC in these villages. CASC could have started giving training and technical support earlier than in other regions. Farmers who have more experience and see the impact of cover crops are also more satisfied. Farmers giving a mediocre mark, between five and seven, need additional training and technical support to understand what cover crops are and how to grow them efficiently. Another sign of the satisfaction of CA- and CT (CA*)-farmers was their recommendation for CT farmers to start growing cover crops. Fourteen out of 18 farmers recommended that CT farmers grow cover crops. Thirteen out of 21 CT farmers are willing to start growing cover crops, mainly because of the constraints that pushed CA farmers to start growing them: soil fertility problems, weed suppression, and soil erosion. This shows that farmers know their orchards' challenges and are ready to adopt any available technique to solve them. Some farmers still prefer to invest in annual crops like corn and cassava because they are more profitable than cover crops. Halbrendt et al. (2014) found that short-term variability, independent of positive, negative or neutral, after introducing CA practices can reduce farmers' attractiveness towards this technique. Farmers' beliefs towards CA may be based more on personal experience and inter-generational knowledge than scientific facts (Halbrendt et al., 2014). This study partly agrees with Halbrendt et al. (2014), confirming that inter-generational beliefs and knowledge can influence farmers' perspectives about CA more than scientific facts. Nevertheless, it disagrees that short-term positive effects discourage farmers' attractiveness. It is important to note that a few farmers led this study from a specific province of Cambodia. The data, being self-reported, can introduce bias. The results have a limitation in generalising respondents' situation to other Cambodian farmers. Moreover, the interviewed CA and CT (CA*)-farmers have been contacted by CASC before, causing the unrandomised nature of the knowledge and experience about CA and, therefore, of the data.

Farmers' reasons for applying cover crops in mango and longan orchards

The presence of weeds under and between the trees and the use of chemical herbicides and labour to cut them, which increased the production costs, convinced farmers to start growing cover crops in their orchards. Soil infertility and soil erosion problems remain a challenge in Battambang province. During the interviews, farmers from Sangha village claimed that soil erosion was the main reason for them to

start growing cover crops. Despite that, during the FGD, they ranked "soil erosion" as the eighth constraint (out of 10) in the orchard that covers crops should be prevented. At the same time, farmers from Borun village also stated soil erosion as the main challenge, both in the interviews and in the FGD. According to the household interviews, pests and diseases are not sufficient for farmers to start growing cover crops. However, farmers in Borun village during the FGD ranked "Pests & Diseases" as the third constraint (out of 10) that cover crops should prevent. These differences between individual interviews and collective FGDs can be explained by the multitude of points of view shared during the discussions that can change people's minds. According to Giacalone et al. (2021), cover crops can take on the role of refuge for beneficial insects, which can control pests biologically and pollinate the main crop. Farmers could use this evidence to promote cover crops.

Snapp et al. (2005) Farmers are usually unwilling or unable to start new technologies like cover crops. The most mentioned reason that keeps farmers from starting to grow cover crops is the lack of knowledge about CA and cover crops, an example of inability. Some interviewees have never heard about these two concepts and have no idea what they are and how to implement them. This lack of awareness can be solved through CASC's training and knowledge sharing between farmers, and more farmers can start growing cover crops. Farmers who claimed not know what CA and cover crops come from all interviewed villages and are of different ages and genders. Other reasons that hold back farmers from starting to grow cover crops were classified as "lack of interest/income". As Snapp et al. (2005) Say, some reasons not to start are influenced by the willingness. Some farmers are still reluctant because nobody grows cover crops in the village. The judgement from other villagers is still being determined, and only a few take the risk of being the first CA farmers in the village.

Opportunities and constraints of cover crops in mango and longan orchards

Four cover crops are grown by 14 CA farmers and four CT (CA*)-farmers in Rattanak Mondoul and Banan districts: sunn hemp, *Arachis repens*, *Arachis pintoi* and peanut. According to Wei et al. (2021) *Brachiaria eruciformis* and Butterfly pea (*Clitoria ternatea)* have a higher impact on mango yield and a better fruit tree quality than Stylo (*Stylosanthes guianensis)*. This does not prove that Stylo cannot be used as a cover crop or forage in mango orchards. It can be used as a soil fertility improver, providing soil N, and as a fodder crop for livestock. These three varieties could be studied in mango and longan orchards in Battambang province, and their effectiveness can be verified. It would allow farmers to have a diversity of cover crops on their farms and between them. Farmers tend to choose the cover crop variety by trusting CASC's recommendations or seeing what other farmers grow. They do not know the difference between the varieties. In some cases, other varieties can be used for other purposes (e.g., as fodder for livestock or as food for human consumption). As Snapp et al. (2005) The farmer should choose the type of cover crop wisely to prevent costs and profit from benefits. Since farmers are not informed enough about all kinds of cover crops, CASC, extension entities or private seed companies should recommend a specific cover crop after analysing the farm and the farmer's objectives.

A proof of the advantages of cover crops that can convince farmers to grow them and decrease production costs is the lack of constraints if they are cultivated correctly. Now, it is important to explain to farmers that covering crops also has challenges. However, if grown correctly, the incidence rate of weed appearance, pests and diseases, soil erosion and soil infertility is low.

According to Creamer et al. (1997), 13 legume cover crop varieties and mixtures achieved 30% ground cover a month after planting and 100% after three months. Only two farmers complained that cover crops take a long time to grow and show their impact. From a personal point of view, the number of farmers complaining about this constraint was expected to be higher.

Cover crops' use expansion from Farmers' perspective

Eighteen 18 farmers claimed that if cover crop seeds were given for free, CT farmers would be more interested and willing to start growing

them. Unfortunately, this would not be possible since other stakeholders from the private sector are involved. Some CA farmers also think that if seeds were given for free, their value would decrease, and farmers would not care for them properly. Some farmers suggested controlling the seed market themselves. In Sangha village, some farmers are already doing it: they produce cover crops seeds, keep apart for themselves and sell the rest to other farmers. A cooperation of seed producers could be founded with insurance in case of bad weather or pest attacks. Some farmers also pointed out that they prefer to grow grass for livestock instead of cover crops. New varieties different from sunn hemp, *A. repens*, *A. pintoi*, and peanuts should be presented to farmers to allow them to be used as fodder for cattle. Several farmers agreed that if field workshops and training were done in collaboration with CA farmers showing their cover crop fields, CT farmers would be interested in starting to grow them. The proof that other farmers succeeded could drop their prejudice about CA and cover crops.

CONCLUSION

After 39 interviews and two FGDs in Battambang province, this study concludes that seventeen interviewed farmers know entirely or partially the definition of CA, but still 21 do not. The satisfaction rate of CA and CT (CA*)-farmers about cover crops is high, leading to a recommendation for adoption for CT farmers. Thirteen CT farmers would be ready to start growing cover crops. Meanwhile, some would still like to explain CA and its benefits. Three main reasons to start growing cover crops in Rattanak Mondoul and Banan districts are weed suppression, improved soil fertility, and decreased soil erosion. Since growing cover crops, CA- and CT (CA*)-farmers observed an improvement in these three factors in their mango and longan orchards. The main reasons why farmers are held back from growing cover crops are mainly because of a lack of knowledge about CA and cover crops. This impedes them to inform themselves and adopt more sustainable techniques. From the farmers' perspective, more training and technical support are needed. Four kinds of cover crops are used, especially to be left on the soil and to be sold. Despite their good impacts on soil fertility, weed control and soil moisture keeping, livestock keepers must use new varieties as animal feed.

Recommendations

The recommendations from the author are destined to three targets: the Department of Land Resources and Management/Conservation Agriculture Service Center (DALRM/CASC) and extension services in Cambodia, the Innovation of Sustainable Agriculture (ISA)- a project of Swisscontact and its partners, and the National University of Battambang (NUBB) and other academic and research institutes in Cambodia. DALRM/CASC could provide more training about CA and cover crops also in another province of the country, inviting CA farmers to show their cover crop fields. It could find new varieties interesting for all kinds of farmers/orchards: cattle keepers, lack of space under or between the trees, lack of sun under the trees, etc. New cover crop varieties, like *Brachiaria eruciformis*, Stylo (*Stylosanthes guianensis*), Butterfly pea (*Clitoria ternatea*) and pigeon pea (*Cajanus cajan*), could be tested to be used in the fruit tree sector. Furthermore, it could promote knowledge sharing between farmers and founding village organisations that promote CA workshops. The ISA project of Swisscontact and its partners could discuss cover crop prices with seed sellers to allow poorer farmers to adopt cover crops and CA and share the current results/knowledge with all the project stakeholders to update them about the current situation and farmers' needs. NUBB and other institutes could promote the study of cover crops and CA for Bachelor, Master and PhD students to allow progression in CA techniques in Cambodia. Further studies about the correlation between gender roles and the implementation of CA and comparing the economic costs and benefits of CA and CT farmers could be done.

Limitations

The first limitation of this study was the limited number of scientific papers about CA and cover crops in Cambodia. The implementation of these techniques is recent in the country. Growing cover crops in the fruit tree sector is still an innovative approach.

The study's main limitation was contacting the survey target group, the farmers to

interview. Contacting the farmers was quite frustrating because there was a lack of answers, and the phone number on the contacts list was nonexistent. When farmers would not answer the phone or the phone number was wrong, we asked other villagers where the farmers lived. The problem in small villages in Cambodia is that people often have nicknames that are known only to them. When we used to ask for a farmer with his real name, nobody knew who we were talking about. We had to exclude some farmers from the research because we could not identify them.

The FGDs also faced some limitations. The first limitation was the bad weather conditions: the rainy day of the first FGD in Borun held back farmers from going out and coming to the FGD. The FGD in Sangha was interrupted by a strong storm where farmers could not be heard, and in the audio and video recording, it was impossible to hear their words. The second limitation was the participation of the farmers in the FGDs. The reasons for their absence can be several, including lack of time and interest. Ultimately, we managed to attract enough farmers to participate in the FGDs and have enough data.

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Declarations

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Conflict of Interest

The authors declared that they have no conflict of interest.

Ethics approval

Not applicable.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent for publication

The authors affirm that participants provided informed consent for publication.

Data availability

Not applicable.

Code availability

Not applicable.

Authors contributions

Conceptualization, S.M. and A.G.; Methodology, S.M. and A.G.; Investigation, S.M., R.R. and P.P.; Resources, F.T. and V.S.; Writing – Original Draft, S.M.; Writing – Review & Editing, S.M., A.G. and F.T.; Visualization, S.M. and A.G.; Supervision, A.G.; Project administration, A.G. and S.R.; Funding acquisition, S.M.

REFERENCES

Arnfield, A. (2022). Köppen climate classification. Britannica.Com. https://www.britannica.com/science/Koppen-climate-classification

Barman, A., Saha, P., Patel, S., & Bera, A. (2022). Crop Diversification an Effective Strategy for Sustainable Agriculture Development. In V. Meena, M. Choudhary, R. Yadav, & S. Meena (Eds.), Sustainable Crop Production (p. 208). IntechOpen. https://doi.org/10.5772/intechopen.102635

Boulakia, S., Kong, R., & Eberle, M. (2013). Sustainable Farming to Sustain Cambodia's Future. https://www.youtube.com/watch?v=lZRAfkP52iM

Climate ADAPT. (2019). Conservation agriculture. Climate-Adapt. Eea. Europa. Eu. https://climate-adapt.eea.europa.eu /en/metadata /adaptation-options /conservation-agriculture/#

Climate Change Knowledge Portal. (no date). Cambodia Climatology. https://climateknowledgeportal.worldbank.org/country/cambodia/climate-data-historical

CountryReports. (no date b). Cambodia Geography. CountryReports. https://www.countryreports.org/country/Cambodia/geography.htm

Creamer, N., Bennet, M., & Stinner, B. (1997). Evaluation of Cover Crop Mixtures for Use in Vegetable Production Systems. HortScience, 32(5), 866–870.

Dinesh, R., Suryanarayana, M. A., Ghoshal Chaudhuri, S., & Sheeja, T. E. (2004). Long-term influence of leguminous cover crops on the biochemical properties of a sandy clay loam Fluventic Sulfaquent in a humid tropical region of India. Soil and Tillage Research, 77(1), 69–77. https://doi.org/10.1016/j.still.2003.11.001

Evans, S. (2022). A Design Response for Sustainability: In the Time of Covid19. In G. Bruyns & H. Wei (Eds.), [ ] With Design: Reinventing Design Modes (pp. 960–972). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-4472-7_62

Fageria, N., Baligar, V., & Bailey, B. (2005). Role of Cover Crops in Improving Soil and Row Crop Productivity. Communications in Soil Science and Plant Analysis, 36(19–20), 2733–2757. https://doi.org/10.1080/00103620500303939

Ferreira Dias, A., Giongo, V., da Silva Barros, V., Müller Carneiro, J., & Brito de Figueirêdo, M. (2020). An agile approach for evaluating the environmental-economic performance of cropping systems at experimental stage: The case of Brazilian mango. The International Journal of Life Cycle Assessment, 25(8), 1588–1604. https://doi.org/10.1007/s11367-020-01772-2

Giacalone, G., Peano, C., Isocrono, D., & Sottile, F. (2021). Are Cover Crops Affecting the Quality and Sustainability of Fruit Production? Agriculture, 11(12), 1–10. https://doi.org/10.3390/agriculture11121201

Halbrendt, J., Gray, S. A., Crow, S., Radovich, T., Kimura, A. H., & Tamang, B. B. (2014). Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture. Global Environmental Change, 28(1), 50–62. https://doi.org/10.1016/j.gloenvcha.2014.05.001

Hin, P. (2019). Contract farming will boost mango processing capacity. The Phnom Penh Post. https://www.phnompenhpost.com/business/contract-farming-will-boost-mango-processing-capacity

Hom, P. (2022). Longan exports to China expected in September. The Phnom Penh Post. https://www.phnompenhpost.com/business/longan-exports-china-expected-september

Kienzle, J., & Njenga, B. (2016). Conservation Agriculture. FAO, 2.

Kong, R., Castella, J., Suos, V., Leng, V., Pat, S., Diepart, J., Sen, R., & Tivet, F. (2021). Investigating farmers' decision-making in adoption of conservation agriculture in the Northwestern uplands of Cambodia. Land Use Policy, 105, 1–12.

Legoupil, J., Lienhard, P., & Khamhoung, A. (2015). Conservation Agriculture in Southeast Asia. In Conservation Agriculture (Farooq Muhammad and Siddique Kadambot H.M., pp. 285–310). https://agritrop.cirad.fr/584727/

Lehmann, J., da Silva, J., Trujillo, L., & Uguen, K. (2000). Legume Cover Crops and nutrient Cycling in Tropical Fruit Tree Production. Acta Hortic, 531, 65–72.

Roberts, R., Abbas, R., Ayyaz, S., Baker, I., Beyer, R., Brown, E., Duthie, R., Johnson, P., Kristedi, T., Kumar, S., Macintosh, H., Markham, R., Nguyen, V., Oakshott, J., Pagnchak-Roat, M., Palanivel, H., Prowse, W., Sophornthida, L., & Wandschneider, T. (2019). Final report. Small research and development activity. Analysis

of mango markets, trade and strategic research issues in the Asia-Pacific. Australian Centre for International Agricultural Research.

Schall, N. (2020). Guidelines for exporting longans from Cambodia to China. GIZ (Deutsch Gesellschaft für Internationale Zusammenarbeit), GDA (General Directorate of Agriculture of the Ministry of Agriculture, Forestry and Fisheries).

Snapp, S., Swinton, S., Labarta, R., Mutch, D., Black, J., Leep, R., Nyiraneza, J., & O'Neil, K. (2005). Evaluating Cover Crops for Benefits, Costs and Performance within Cropping System Niches.

SoCo, (Sustainable agriculture and soil conservation). (2009). Conservation Agriculture. European Communities. https://esdac.jrc.ec.europa.eu/projects/SOCO/FactSheets/ENFactSheet-05.pdf

The World Bank. (2015). Cambodian Agriculture in Transition: Opportunities and Risks.

Thou, V. (2021). Thailand expected to open door to Cambodian longan. The Phnom Penh Post. https://www.phnompenhpost.com/business/thailand-expected-open-door-cambodian-longan

Vernet, P.-A., Faysse, N., Suos, V., Oung, N., Son, S., Leng, V., Rendall, T., Lor, L., Reyes, M., Chan, S., Pradhan, R., Vang, S., & Tivet, F. (2020). Investing in a no-till planter in Cambodia: A promising opportunity for certain categories of service providers. 2020(1).

Wei, Z., Zeng, Q., & Tan, W. (2021). Cover Cropping Impacts Soil Microbial Communities and Functions in Mango Orchards. Agriculture, 11(343), 12. https://doi.org/10.3390/agriculture11040343

Won, S. (2021). Cambodian mango goes to China. Tridge. https://www.tridge.com/stories/cambodian-mango-es-into-china?