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Women farmers preferences of improved tools and impact of conservation agriculture practices on yield and profitability of commercial vegetable home gardens in Cambodia

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Abstract

In Cambodia, labour movement from on-farm towards off-farm jobs is one of the causes of reduced availability of agricultural workers. Conventional vegetable production requires a lot of strenuous labour for land preparation. Conservation agriculture (CA) has been promoted globally as one of the options to enhance soil, water, and biodiversity health, reduce labour and its drudgery, arrest land degradation, and provide drought and flood resilience amidst climate change. However, limitation of market-available garden tools on conservation agriculture is a factor for slow adaptation of CA in Cambodia. Ergonomic tools that are safe, appropriate for women and men, and can be manufactured locally are needed for CA adaptation. The objectives of this study were to: (a) evaluate potential CA tools based on ergonomics, affordability, efficiency, can be locally manufactured and women and men friendly; and (b) quantify the impacts of CA practices compared with conventional tilled practices on yield and profitability of key vegetables crops in commercial home gardens managed by women in Cambodia. Hand tools were introduced to CA women farmers for at least two months prior to the tool test. Work efficiency and adaptation feedbacks were evaluated for each tool used for planting, weeding, fruit covering, and harvesting from thirteen practicing CA farmers. We found that hand tools which are lightweight with multiple functions and requiring less manual force, hence providing least discomforts were most preferred. We identified those tools in this paper. In addition, we recommend affordable drip irrigation. CA was found to produce more vegetables than CT, with less labour and cost. We recommended ergonomically safe, affordable, efficient, and women friendly tools for CA commercial vegetable home gardens.

Keywords: commercial vegetable production, conservation agriculture, garden hand tool, no-till farming, women farmer.

Introduction

Agriculture is one of the most important sectors of Cambodia for its economic growth and food security. More than 70% of population is directly or indirectly involved in the agri-food system. The resilient and diversified agricultural system will be critical for supplying affordable, safe and nutritious food for healthy being of the population. Agricultural production in Cambodia is predominantly based on rice, however, in recent years there has been significant emphases on production of vegetables. There is high demand for vegetables and at present only 25% of the needs are met by local production in Cambodia, and rest if the needs are fulfilled by imports from Thailand and Vietnam. This incurs a large economic cost to Cambodia. Local vegetable production grew only 10%, while cassava grew 51% (World Bank 2015). Lack of vegetable production also impacts the nutritional needs of the population, particularly women and children. A recent report of the FAO indicated that about 14.5% and 13.6% of the population suffers from undernutrition and food insecurity, respectively. In addition, 32.4% of the children under five years of age are stunted (Global Nutrition Report 2020). The per capita consumption of vegetables in Cambodia is low and one of reasons of malnutrition and micronutrient deficiencies in children and women in Cambodia. Local production and

consumption of vegetables will be key to addressing food and nutritional security. Production of commercial vegetables will allow for diversification of agri-food systems due to presence of diver crops that are short duration. In addition, vegetable production on commercial home gardens can provide income to the smallholder farmers to reduce the risk and help with building resilience.

Vegetable production in Cambodia is primarily done by women, especially on the home gardens and rice fallows. The income from vegetables sales has the potential for help women, compared to staple or cash crops that are more supportive to men. These vegetables provide direct access to diet diversity and supply important nutrients to families. The migration of men to cities and labour movement from on-farm towards off-farm, further enhanced the stress on women to stay and work at farms at home. However, conventional farming management practice for vegetable production is labour intensive and labour shortage in the rural areas is one of the main causes of slow progress for vegetable production in the country (Chhim et al. 2015; Sims and Kienzle 2015). Most of the tools currently used in vegetable production system are old and made at home.

There is a limitation of market-available garden tools use for vegetable home gardens due to disconnection of local tool makers and farmers. Generally, basic and weighty tools (e.g., grub hoe, spade, and hand-tractor) are used by women farmers. These tools usually required significant effort, are not friendly for women farmers and cause human ergonomic discomfort and risk for vegetable production. Efficient and improved hand tool designs are essential in reducing the ergonomic risk factors for users, and there are several garden-hand tools that are available and can be tested and introduced to women farmers in Cambodia. However, a comprehensive collection and evaluation of these tools has not been done and needed. Identification and introduction of appropriate ergonomically safe, affordable, efficient, and women friendly tools for particularly that can be used in commercial home gardens grown using principles of conservation agriculture.

Conservation agriculture (CA) consists of a range of cropping systems based on a combination of three main principles (Lal 1997): (i) soil tillage reduction, (ii) soil protection by organic residues and (iii) diversification in crop rotation. The CA concept has been promoted globally, it has been considered as one of the options to enhance soil health, reduce labour and its drudgery, and save water (Pretty et al. 2002; Knowler and Bradshaw 2006; Ares et al. 2015; Edralin et al. 2017). The CA practice management would achieve a sustainable crop production under condition of uncertainties of climate change, both for large- and small-scale farmers (Pretty 2008; Scopel et al. 2012; Palm et al. 2014; Edralin et al. 2016). CA vegetable production with drip irrigation have been introducing to women farmers in Siem Reap, Cambodia since 2013, to reduce farmer labour and helps the environment while improving soil quality, in order to engage women in vegetable production for food security (Edralin and Reyes 2013). Engaging women in conservation agriculture commercial vegetable home garden production systems, which enhances soil health, improves nutrient intake, increases yield and provides economic opportunity at household level. Although there are some studies that has shown the benefits of using conservation agricultural practices on yield of vegetable crops in part of Cambodia (Edralin et al. 2017; Hin et al. 2020). They are not focused solely focused on women farmers and their ability manage these gardens. The impact of using CA practices in commercial home gardens managed by women farmers is limited and needs attention.

Therefore, the objectives of this research were to (a) evaluate potential CA tools based on ergonomics, affordability, efficiency, can be locally manufactured and women and men friendly; and (b) quantify the impacts of CA practices compared with conventional tilled practices on yield and profitability of key vegetables crops in commercial home gardens managed by women in Cambodia.

Methods

Study region

This research was conducted in Battambang region in the northwest part of Cambodia. Battambang is one of the key commercial vegetable production regions with access to local and regional market. Fifty women farmers in Battambang, Cambodia were formed up as a 'Women Farmer Network' in January 2018 for production of commercial vegetable home garden adapting CA principles with drip irrigation systems. The farmers were trained and assisted to set up CA plots utilizing drip irrigation systems in Banan, Ek Phnom and Sangkae districts in Battambang. The CA plots were applied with a combination of three main principles: (i) soil tillage reduction, (ii) soil protection by organic residues (i.e., mainly rice straw) and (iii) diversification in crop rotation (different vegetable species, 3 crop cycles per year). The conventional tillage (CT) plots were tilled and did not use the above principles, and they only produce one cycle of crop in a season. These management practices were adapted by each farmer of 50 women farmers since 2018. The soils of the study areas were classified by Crocker (1962) as Brown Hydromorphic soil group, with clay (~50%) soil texture, more details on soil chemical and physical properties were described in Srean et al. (2012).

Evaluation of Various Tools in Commercial Home Vegetable Gardens

To identify the best garden tools for commercial vegetable home garden production for the main tasks of vegetable farming included planting, weeding, fruit covering, and harvesting. Nineteen different types of hand tools commonly used in CA practices and farmer's

recommendation were included in the study and these tools were brought from the United State of America (USA), France, Thailand, Japan, and Cambodia (Table 1). The tools were specifically used for planting, weeding, fruit covering and harvesting. Prior to the tests, the tools were introduced, and their use was explained to the CA women farmers for 2 – 3 months. The nineteen types of hand tools and manual practice were identified for specific tasks, were evaluated their efficiencies of performances for planting, weeding, fruit covering, and harvesting.

Thirteen CA women farmers with age ranked from 29 to 55 years old involved in the test in April – June, 2018. Each tool was used by the farmers to test work done per hour for specific task performed for planting, weeding, fruit covering and harvesting. The test period was varied ranged from 2 to 30 minutes per test, depending on task performance types. The individual work done was converted to wok done per hour of the task performance for planting hole making (number of holes made), weeding (m2 of land area), harvesting (number of fruits), and fruit covering (number of covers).

After testing, feedbacks on tool preference were collected from face-to-face interview with farmer for each hand tool using a survey instrument. Data on human ergonomics risk assessments of each tool were also included. The use of these tools was tested in their commercial home vegetable gardens. Vegetables growing during the studies included bitter gourd (*Momordica charantia*), chili (*Capsicum annuum*), climbing wattle (*Senegalia pennata*), cucumber (*Cucumis sativus*), eggplant (*Salanum melongena*), okra (*Abelmpchus esculentus*), sponge gourd (*Luffa aegyptiaca*), and yardlong bean (*Vigna unguiculate*).

To test the tool efficiency, the work done per hour of each tool was compared, using Krusal-Wallis test along with post hoc tests for nonparametric analysis of variance to test whether or not significant different among the tools used for the planting, weeding, fruit covering and harvesting. The feedbacks on using the tools were computed as percentage for the human ergonomic impact on their body parts (i.e., neck, hand, wrish, leg and shoulders). All statistical analyses were performed using R software of version 3.6.1 (R Core Team 2019).

Impact of CA on Yield and Profitability of Commercial Home Vegetables Gardens

A comparison study was conducted to estimate yield and profitability of commercial home vegetable production using CA and CT management practices. There were 18 CA farmers and 42 CT farmers in this research. Three crop cycles per year were performed for CA and only one cycle for CT. The vegetable crops grown in each plot were shown in Table 2. The farmers were interviewed to collect data on vegetable types grown in 2017 and 2018, crop cultivated area, productivity per unit area per cycle, direct cost of crop production, and crop revenue. To estimate the profitability of each crop per unit area, all the numeric data of variables were converted to value per 200 square metre of land area. The gross margin was calculated by subtracting the direct cost of crop production from the crop revenue. The direct cost of crop production included fertilizers, seeds, labour, land preparation, energy for irrigation, pesticide used, and cost of irrigation systems for CA versus CT management practices. The CA has the drip irrigation systems while CT has the traditional irrigation using water cans. Benefit cost ratio was estimated to indicate as return on investment for each vegetable crop. Value of the benefit cost ratio indicated investment return from $1 spent for direct cost of production for each crop. When the benefit cost ratio is greater than 1 indicates the production is profitable and a ratio is less than 1 indicates that it is unprofitable.

All the comparisons between CA and CT were illustrated for boxplots, using 'ggplot2' R package (Wickham 2011). To distinguish overall characteristics of CA and CT, the Principal Component Analysis (PCA) was visualized, using 'factoextra' R package (Kassambara and Mundt 2016). All the variables, i.e., the total direct cost, energy, labour, land preparation, pesticide, fertilizer, seed, vegetable price, drip irrigation, cultivation area, revenue, and gross margin of the CA and CT were included in the PCA analysis.

Table 1: Hand tools used in the study, and their size, weight and commonly used in the tool evaluation; and their source of origin.

No.	Pictures	Hand Tools	Size and Weight	Commonly used, and Source of Origin
1		Bulb Planter, with long handles and automatic release	• Weight 0.431 kg • Length 19 cm	• Digging hole for planting • European model modified in Cambodia for long handles
2		Spade	• Small size • Weight 0.267 kg • Length 46 cm	• Digging hole for planting • Thailand

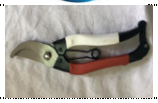
3		Weasel Bulb Planter	• Weight 1.8 kg • Length 101.6 cm	• Digging hole for planting • USA
4		Cape Cod Weeder	• Weight 0.1kg • Length 20 cm	• Weeding • Japan
5		Grass Cut Sickle	• Weight 0.15 kg • Length 30 cm	• Weeding • Japan
6		Carving Knife	• Weight 0.080 kg • Length 20 cm	• Weeding • Thailand
7		Hooked knife	• Weight 0.555 kg • Length 54 cm	• Weeding • Thailand
8		Putty knife	• Weight 0.203 kg • Length 18 cm	• Weeding • Thailand
9		Big sickle	• Weight 0.146 kg • Length 33 cm	• Weeding • Cambodia
10		Grub hoe	• Weight 1 kg • Length 120 cm	• Weeding • Thailand
11		Prohoe Rogue Garden Hoe	• Weight 0.4 kg • Length 152.4 cm	• Weeding • USA
12		Digger bundle	• Weight 0.5 kg • Length 17.78 cm	• Weeding • USA
13		Long Batwing Hoe	• Weight 0.5 kg • Length 151.13 cm	• Weeding • USA
14		Push Pull Hoe	• Weight 0.5 kg • Length 175.26 cm	• Weeding • USA
15		Wheel hoe weeder	• Weight 2 kg • Length 100 cm	• Weeding • Modified in Cambodia
16		Stapler	• Weight 0.079 kg • Length 15 cm	• Fruit covering • Thailand
17		Plastic String		• Fruit covering • Thailand
18		Pruner	• Weight 0.208 kg • Length 21 cm	• Harvesting • Thailand
19		Scissor	• Weight 0.2 kg • Length 20 cm	• Harvesting • Thailand

Table 2: Vegetable crops and number of crops grown in each crop cycle for CA and CT plots in 2017 and 2018.

		CA						CT		
		Cycle 1		Cycle 2		Cycle 3		Cycle 1		Sub-total
No.	Crops	2017	2018	2017	2018	2017	2018	2017	2018	
1	Bitter gourd	0	5	0	1	0	8	0	0	14
2	Cauliflower	3	0	0	0	0	0	0	0	3
3	Chili	2	0	0	1	0	1	4	3	11
4	Chinese kale	0	0	0	0	2	0	0	0	2
5	Cucumber	11	0	3	0	5	0	2	0	21
6	Eggplant	0	0	0	0	3	0	1	0	4
7	Okra	3	0	0	0	1	0	0	0	4
8	Sponge gourd	3	2	0	0	0	1	0	1	7
9	Wax gourd	1	2	0	0	0	0	0	3	6
10	Yardlong bean	8	4	12	11	1	3	0	14	53
	Total	31	13	15	13	12	13	7	21	**125**

Results

Evaluation of Various Tools in Commercial Home Vegetable Gardens

The nineteen hand tools and manual used and practiced in the CA vegetable home gardens, adapted by women farmers and provided different efficiencies depending on types of the hand tools (Table 1). There were significant differences among different tools.

Planting: Three primary tools were used and evaluated for planting (Fig. 1). For planting, efficiency (the number of holes dug per hour) of the bulb planter with long handles and automatic release was significantly greater compared to using traditional spade, whereas the weasel bulb planter was the least efficiency tool for planting (Fig. 1).

Weeding: Thirteen out of nineteen hand tools were used for weeding (Fig. 2). There were significant differences for their efficiencies. These efficiencies were classified into three groups: a) very useful (mean ranged: 27.75 – 31.30 m^2 per hour), i.e., grass cut sickle, prohoe rogue garden hoe, hooked knife, and putty knife, b) useful (mean ranged: 18.16 – 26.30 m^2 per hour), i.e., cape cod weeder, big sickle, grub hoe, gaving knife, digging hoe, and long batwing hoe, and c). not useful (<10 m^2 per hour), i.e., push pull hoe, wheel hoe weeder, and digger bundle.

Harvesting: There were three tools that were evaluated for the harvesting (Fig. 3). The efficiency of manual and pruner were significantly greater than scissor for harvesting and collected fruits and young leave of climbing wattle quicker. Although the pruner could not improve efficiency as comparing with the manual, it could decrease ergonomics risk.

Overall Responses: Responses of the woman farmers to each hand tool used in the conservation agriculture vegetable home gardens for task performances include planting, weeding, fruit covering, and harvesting were shown in Fig. 4. These responses were mainly indicated their impacts on body part discomfort feeling after using them. Among the seventeen using tools, only the pruner and stapler showed no impact on their body part, the other tools showed impacts on neck, hand, wrish, leg and shoulders.

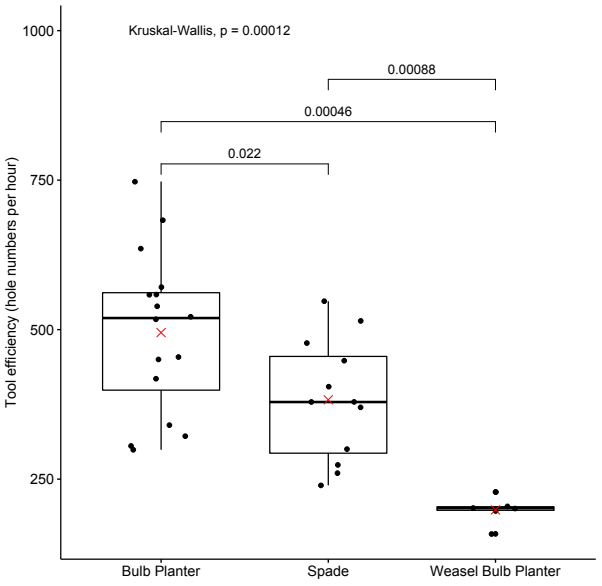


Fig. 1: Boxplot comparing efficiencies of tools used for making planting holes of conservation agriculture vegetable production. Note: the red crosses indicated mean values.

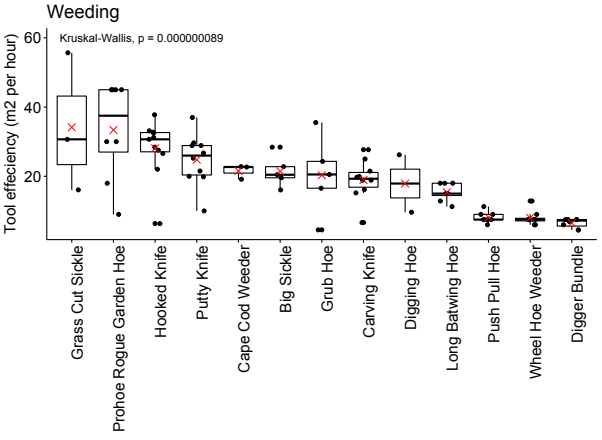


Fig. 2: Boxplot comparing efficiencies (land area per hour of weeding performant) of tools used for weeding of conservation agriculture vegetable production. Note: the red crosses indicated mean values.

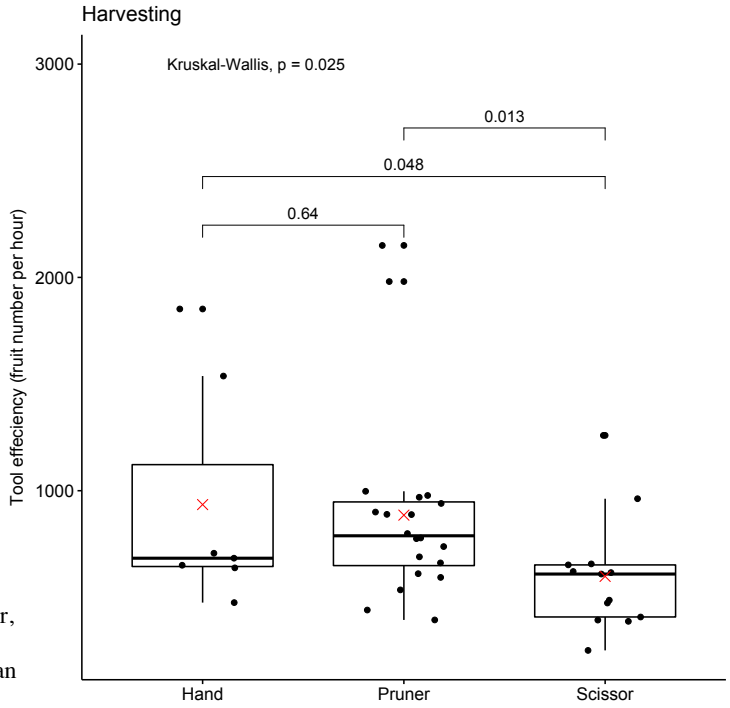


Fig. 3: Boxplot comparing efficiencies of tools used for harvesting fruits of Bitter gourd, Chili, Cucumber, Okra, Sponge gourd, and Yardlong bean or leave of Climbing wattle. Note: the red crosses indicated mean values.

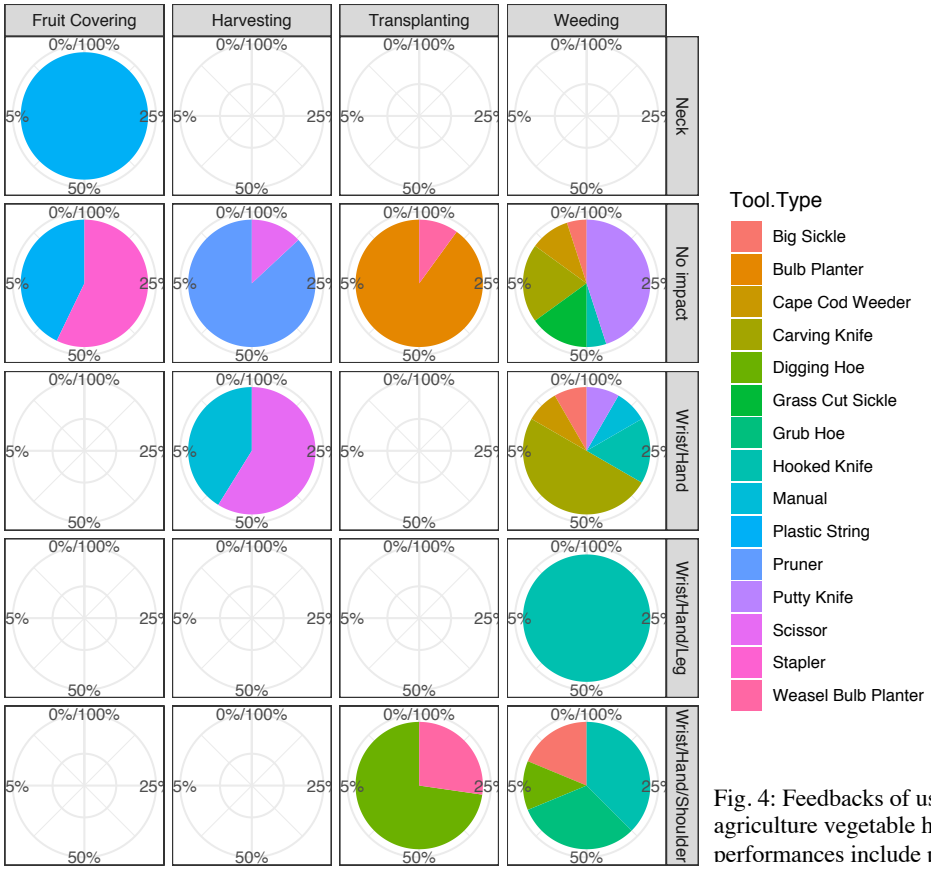


Fig. 4: Feedbacks of using hand tools in the conservation agriculture vegetable home gardens for task performances include planting, weeding, fruit covering,

Impact of CA on Yield and Profitability of Commercial Home Vegetables Gardens

In the commercial vegetable home gardens, seven vegetable types were observed and grown by both CA and CT farmers (Fig. 5). For the CA, three crop cycles per year were applied, whereas only cycle was performed for the CT in a specific period at the end of rainy season, normally, from November to March. Bitter gourd, yardlong bean and cucumber were the most preferable crops in the study areas.

Yield: Crop productivity of bitter gourd was significantly greater (32%) in CA when compared to CT (Fig. 6). Whereas wax gourd and yardlong bean were found were greater under CT than those in CA (Fig. 6). There was no yield comparison for the second and third crop cycle for CT, only CA crops were produced traditional by all farmers.

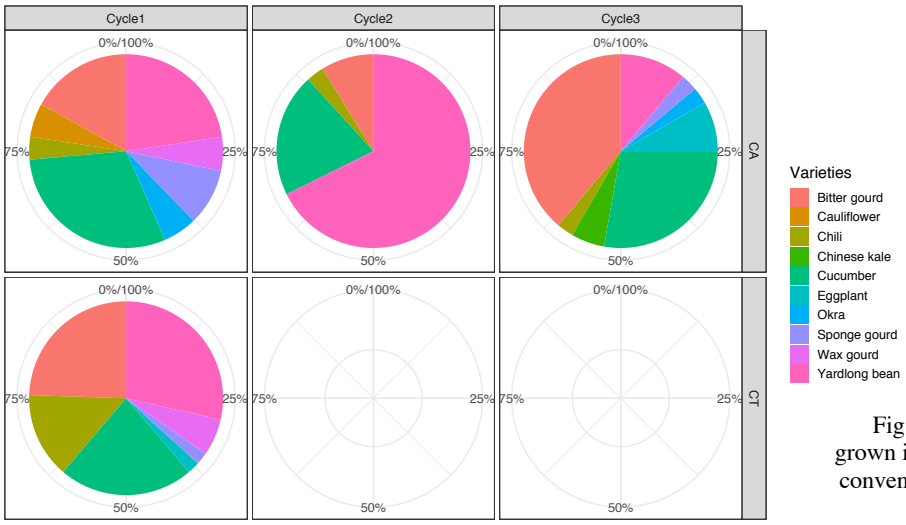


Fig. 5: Proportion of vegetable varieties grown in conservation agriculture (CA) and conventional tillage (CT) for cycle 1, 2 and 3, cultivated in 2017 and 2018.

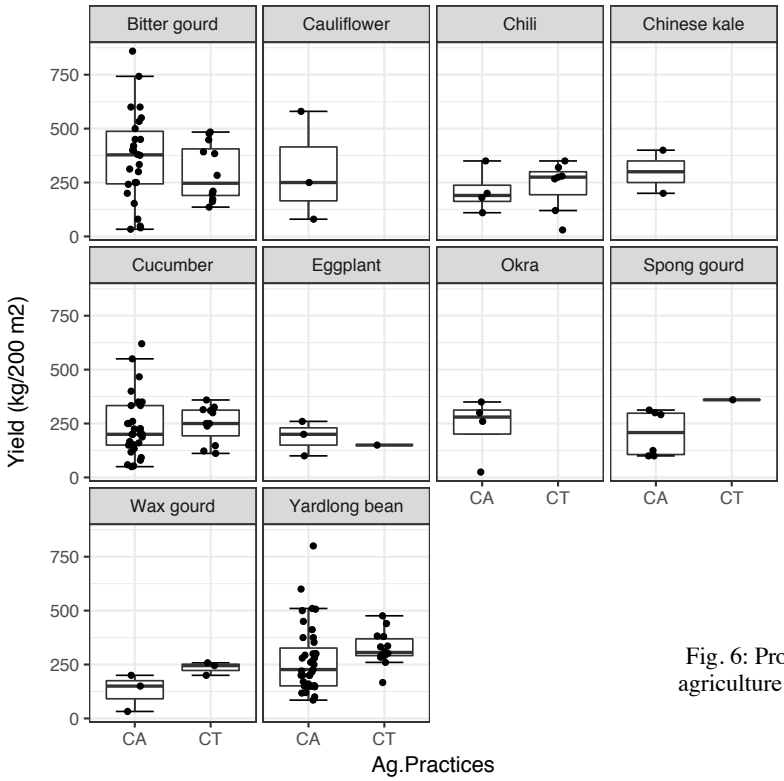


Fig. 6: Productivity of vegetable cultivation in conservation agriculture (CA) and conventional tillage (CT) for each crop cultivated in 2017 and 2018.

Cost of Production: For the direct cost of crop production included drip irrigation, energy, fertilizer, labour, land preparation, pesticide and seed were the main expanses for the vegetable production (Fig. 7). The costs for different crops under CA and CT were different. The drip irrigation cost and cost associated with labour for land preparation and mulching for CA was significantly greater than that for CT. However, the total energy, fertilizer, labour and pesticide were significantly greater in CT than those in CA.

Revenue and Profits: Average revenues were $105.53 (SD: ±119.59) per 200 m^2 for CA and $79.39 (SD: ±96.47) for CT. The revenue was varied depending on crop types and seasonal production. Although profit was not found significantly different between CA and CT for the first year of CA management practice, CA allowed farmers to produce vegetables three times per year. The profitability in CA was highly varied due to ability of farmers adapting new technologies, which was not introduced earlier. It indicated that it would be getting better profitability once the technology was adapted well by the farmers.

Benefit cost ratio: The return on investment varied with crops based on cost, yield and market value depending on crop seasons (Fig. 8). Bitter gourd, Yardlong bean and Sponge gourd showed better response to the CA management practices than other crops.

Overall, although revenue and profitability were not much different between CA and CT, most types of the direct cost of crop production were clearly found in CT, whereas the drip irrigation and seed were costed higher in the CA (Fig. 9). However, the vegetables produced in CA were sold in better price.

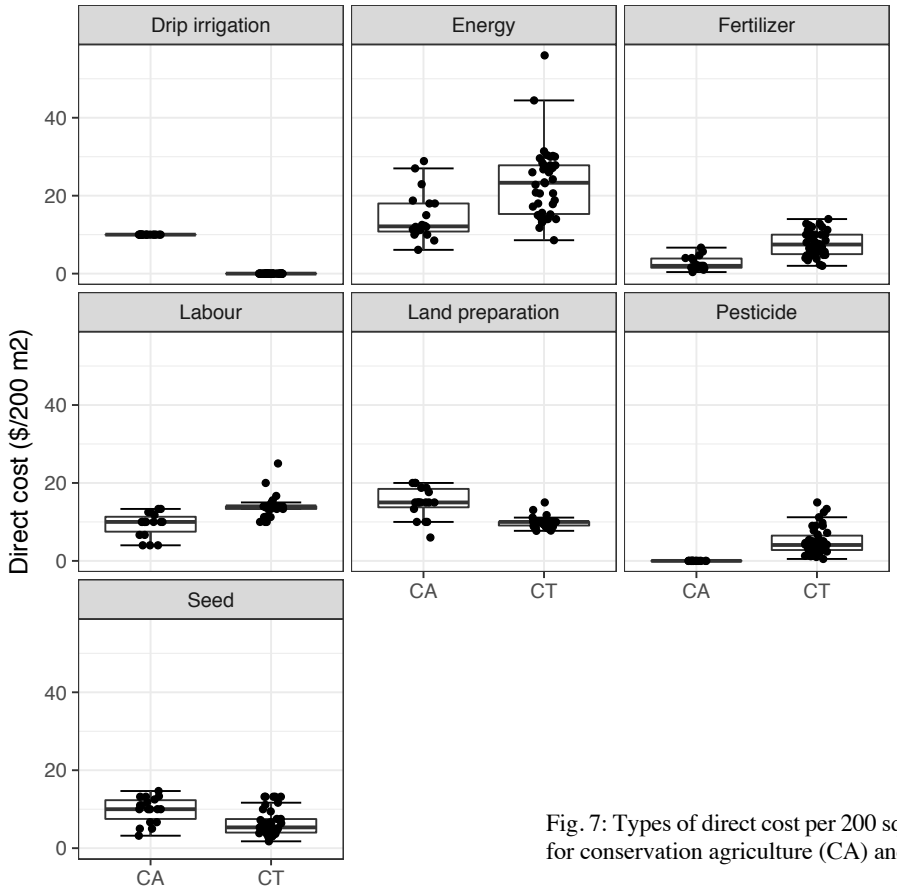


Fig. 7: Types of direct cost per 200 square meter of vegetable cultivation for conservation agriculture (CA) and conventional tillage (CT).

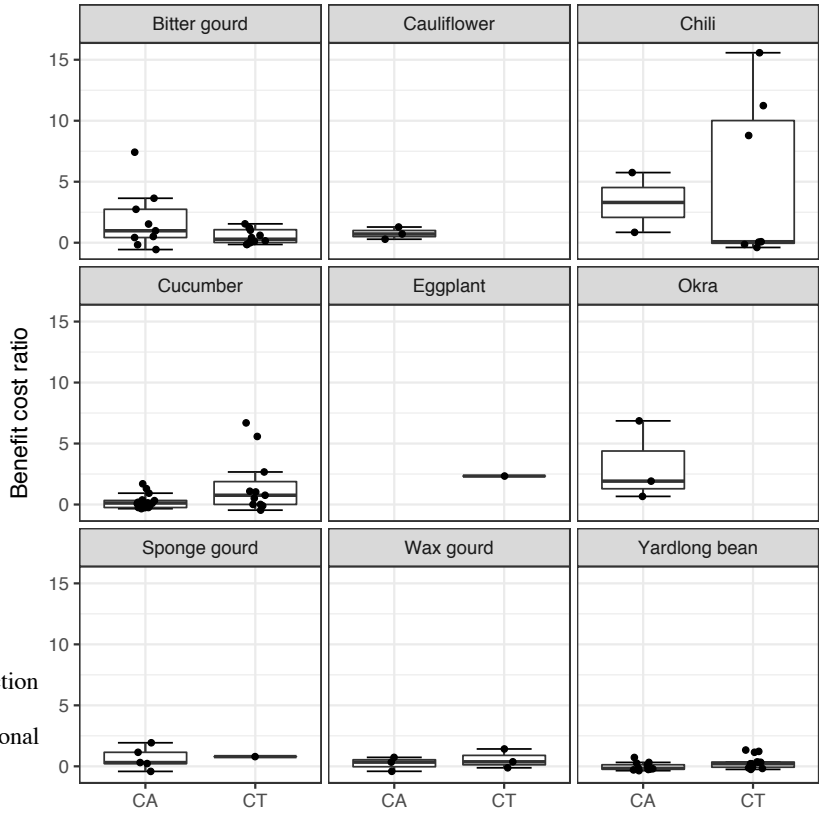


Fig. 8: The benefit cost of vegetable production per 200 square meters for each crop under conservation agriculture (CA) and conventional tillage (CT).

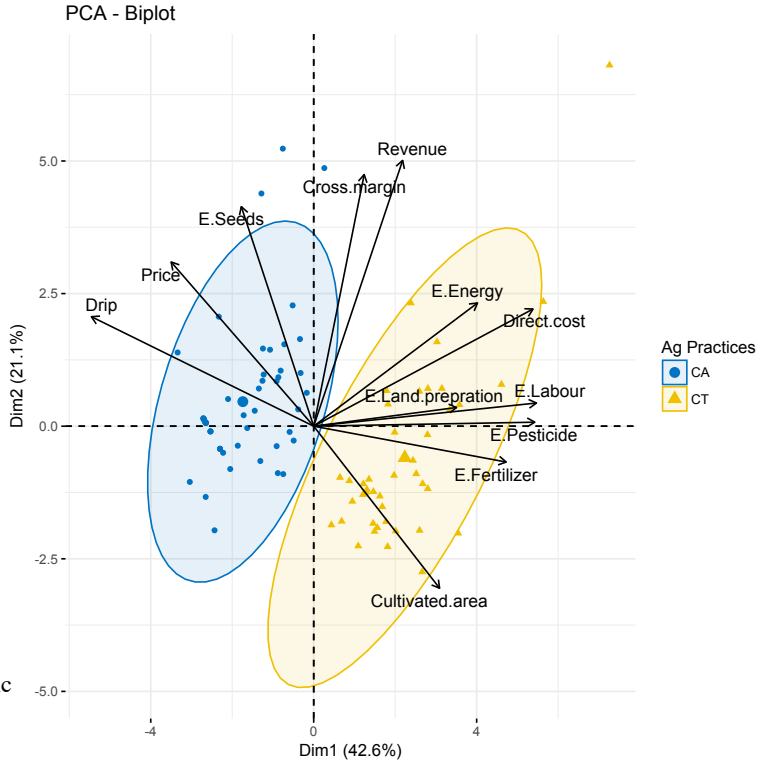


Fig. 9: Principal Component Analysis of economic efficiency (direct cost, cultivation area, revenue, and gross margin) for conservation agriculture (CA) and conventional tillage (CT).

Discussion

This research clearly showed that different tools used for planting, weeding, fruit covering, and harvesting provided different work efficiencies. Some of the tools were more efficient and preferred by women due to their efficiency, design and impact on the human body parts. For planting, the bulb planter with long handles and automatic release was the best for the clay soil conditions, which the soil could be released from the planter. This was primarily due to its design for ease of operation, compared to other which were difficult to operate and most of the time stuck in the soil. Women has to put extra effort to pull out of soil. In addition, the extra-long handle was less impact full back, legs and arms. Therefore these were preferred. For weed control, several hand tools, i.e. grass cut sickle, prohoe rogue garden hoe, hooked knife, and putty knife, were identified as useful tools for weed control due to their effort adaptability, efficiency and comfortability. Some tools were useful and adapted well by the farmers, whereas some other tools were not (i.e., push pull hoe, wheel hoe weeder, and digger bundle) with low efficiency were not preferred by the female farmers due to they were not suit for clay soil condition. Although the pruner used for harvesting was not increase work efficiency comparing to manual practice, it was more comfortable than the manual one as the responses indicated no ergonomic impact on human body parts of the users. The long handles allow workers standing that may reduce lower back stress (Jain et al. 2018). Drudgery reduction by improving hand tools used for farming was recommended for woman engagement in vegetable production system (Mrunalini et al. 2015), and it could improve work efficiency (Shahi et al. 2018). Previous studies (Wibowo and Soni 2014; Jain et al. 2016; Robertoes et al. 2016) have shown that function of hand tools was the first choice of farmers, following by safe, good fit in hand, easy to use, reliable, and handle feels comfortable. In Cambodia, private sector engagement for commercialize agricultural tools and equipment is recommended for providing more market-available tools and equipment use for CA vegetable production; to adapt the combination principles for soil tillage reduction, soil protection by organic residues, and diversification in crop rotation (Lal 1997). The more availabilities of farming tools allowed farmers to reduce labour intensive while the time of labour shortage in the country due to labour have been moving to cities and abroad for economic opportunities (National Institute of Statistics 2015) and promote appropriate technologies for increasing local vegetable production to minimize imported vegetables from Thailand and Vietnam (Sims and Kienzle 2015; Edralin et al. 2017).

Overall, the hand tools with lightweight, multiple functions, less force, and drudgery reduction could provide more work efficiency and adaptability, which were considered as the best hand tools use for CA vegetable home gardens utilizing drip irrigation system. Human ergonomic impacts on body parts of the farmers could be reduced by using introduced hand tools for task performances in the vegetables production. Designing hand tools with work efficiency and drudgery reduction was also recommended. Appropriate, ergonomically safe, affordable, efficient, and women friendly tools for commercial vegetable home gardens are keys for women engagement in agriculture to improve their income and provide nutrient-rich diets at home.

The response of crops varied under CA and CT, with some crops responding positively to yield, while others did not show positive response. The yields of Bitter gourd, Cucumber and Yardlong bean were better in CA plots due to conservation of water, minimize evaporation; which led to increased water use efficiency (Thierfelder and Wall 2009; Sapkota et al. 2014; Yimam et al. 2020).

Although the yields on crops was not responsive in different crops, in most of the crops the use of fertilizer and pesticides were lower in CA that has environmental benefits. Decreased use of fertilizer will decrease the costs and also leaching and loss of nutrients thus protecting the environment (e.g., Palm et al. 2014; Hok et al. 2015; Ranaivoson et al. 2017; Beesa et al. 2021).

Similarly, the lower use pesticides will minimize the negative impact on human health and on environment. Studies have shown that the number of sprays of pesticides used in CA were relatively less compared to those in CT.

Production cost, yield and market value were the main factors influencing on the benefit cost ratio, e.g., Bitter gourd, Yardlong bean and Sponge gourd would respond better to the CA management practices.

Overall, several studies have shown that there are multiple benefits of CA in terms of soil health enhancement and reducing inputs, e.g. fertilizers, pesticides used in the production. The CA is known as minimum soil disturbance and has been considered as one of the options to enhance soil health, reduce labour and its drudgery, and save water (Pretty et al. 2002; Knowler and Bradshaw 2006; Ares et al. 2015; Edralin et al. 2017), therefore, promoting commercial vegetable home gardens under CA management practice is recommended for the context in Cambodia.

Conclusions and Future Direction

We have identified specific hand tools used for specific task of women farmers for vegetable production adapting conservation agriculture practices to improve yield and profitability of commercial vegetable home gardens. The vegetable crops included Bitter gourd, Yardlong bean and Sponge gourd would yield better return on investment.

The tools are recommended to be tested for better adaptation, and modified to minimize human ergonomic discomfort and risk, particularly for woman farmers. Tools use for different soil conditions (e.g., clay or sand) and other task performances, which were not included in

this study should; and soil ecosystem health (i.e., C transformation, nutrient cycling, soil structure and soil macro fauna activity) under CA and CT should be considered for future studies.

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