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Research article

Cases of Climate-Smart Agriculture in Southeast Asian highlands: Implications for ecosystem conservation and sustainability

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Abstract

Importance of the work: Over time, the world's atmospheric concentration of greenhouse gases (GHGs) has increased as a result of human activities. Climate change is expected to affect agriculture in regions with poor and limited resources. For highland people's livelihoods, land resource limitations are constraining the indigenous agricultural systems. Climate-Smart Agriculture (CSA) is a new way of describing practices to achieve triple wins: improve productivity and incomes, support climate change adaptation and reduce or remove agricultural emissions of GHGs.

Objectives: CSA was reviewed as knowledge integration between traditional farming and modern technology in economic, social and agricultural ecology contexts.

Materials & Methods: CSA case studies produced 88 results including multiple strategies for achieving CSA goals. Data were collected from surveys and focus group discussion regarding the highland smallholder agriculture system in Mae Chaem district, Chiang Mai province, Northern Thailand.

Results: The information collated on 10 CSA strategies should assist smallholder farming systems in particular to achieve CSA goals. The advantages and disadvantages of CSA were identified along with keywords used in this overlap search related to CSA. The remaining challenges were considered along with the issues and challenges of Climate-Smart Agriculture.

Main finding: CSA strategies can lead to ecosystem conservation and sustainability regarding highland agriculture, ethnic groups and the United Nation's Sustainable Development Goals.

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Introduction

Currently, farmers in many developing countries, for example, in Southeast Asia (SEA), face poverty and food insecurity due to the deterioration of soils, floods, droughts and ecosystem loss that are vulnerable to climate variability. Farm typologies are socio-economic and ecological factors. The Food and Agriculture Organization of the United Nations and the United Nations reported that the earth's population is projected to reach 9–11 billion by 2050 (Food and Agriculture Organization of the United Nations (FAO), 2010; United Nations, 2017). Global food security is a serious challenge to humanity and has become more serious since the high food price volatility during 2007–2008 that led to setting up the state of food insecurity in the world in 2010 (FAO, 2010, 2013; Lal, 2016). This issue is rising to the center of global discourse and has become an issue of national policies and public concern (Antón et al., 2013). Higher temperature can reduce crop duration, increase respiration rates, affect the survival and distribution of pest populations and may hasten nutrient mineralization in soils, decrease fertilizer-use efficiency and increase evapotranspiration (Graef et al., 2014). In addition, ecosystems will be disturbed and altered due to increasing diseases and pest infestations caused by the temperature rise (Graef et al., 2014). Thus, climate change would substantially affect key components in the four pillars of food security, which are food availability, accessibility, stability and utilization (FAO, 2010, 2015). Therefore, various farm action strategies can be improved that are suitable for the context of the area under climate change.

Southeast Asia

There are 11 countries in SEA: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste and Vietnam. The total population in 2020 was around 668 million, equal to 9% of the total world population (Worldometer, 2020). There are various ethnicities in SEA dwelling in many countries. The majority of SEA has wet and dry seasons (Liu and Dai, 2020). SEA has a total agricultural area of 127 million hectares (United Nations, 2017). In 2020, the total gross domestic product of all ASEAN states amounted to USD 3.08 trillion (FAO, 2015). Rice production is important in the food world amounting to 116.04 million t in 2021 (United States Department of Agriculture, 2022). In addition, SEA member countries have large groups of people that survive on highland subsistence agriculture and are vulnerable (Limnirankul et al., 2015a). The highland areas are inhabited by ethnic groups, who are considered to be in charge of biodiversity (Dearden, 1995). Agriculture is the primary income for an estimated 70% of the world's poor who live in rural areas (World Bank, 2003).

Climate-Smart Agriculture

Climate-Smart Agriculture (CSA) has been defined as agriculture that improve smallholders sustainability, with three goals: to increase productivity, to enhance resilience (adaptation) and to reduce/remove greenhouse gases (GHGs, mitigation) where possible, and to enhance the achievement of national food security and development goals (FAO, 2013; Brandt et al., 2017). There is often a close relationship between increased productivity and adaptation, as increased incomes can reduce climate risks and vulnerability. However, any short-term productivity rise is often achieved at the expense of long-term system resilience. Many impact studies pointed to severe crop yield reductions in the next decades without strong adaptation (FAO, 2010, 2013; United Nations, 2015, 2017). Furthermore, the preferences for CSA technologies in farmers are marked by some commonalities and differences according to their socio-economic characteristics and rainfall zones (Mwongera et al., 2017). The interest in advancing investment in CSA practices is a key pathway that has the potential to important reduce the negative effects of climate change and variability risks on smallholder farmers livelihoods. CSA seeks to overcome the food security problem and develop rural livelihoods while minimizing negative impacts on the environment. The concept of CSA offers a suite of approaches for transforming and reorienting agricultural systems to support food security in the face of climate change by focusing on the potential synergies and trade-offs between agricultural productivity and food security, adaptive capacity and mitigation benefits. CSA has implications for ecosystem conservation and sustainability, as unsustainable agriculture can lead to severe consequences, such as biodiversity loss, soil deterioration, and ecosystem degradation (FAO, 2010). As CSA is dependent on the diversity of ecosystem and species, its practice should lead to ecosystem conservation and sustainability. There are strategic components of CSA aimed to achieve different goals, such as carbon smart, energy smart and nutrition smart, individually or simultaneously. The primary focus of the current study was on farmers' learning and operational preparation to deal with tensions and disasters at the farm level. Understanding the implications of threats from climate change and the recognition of coping mechanisms will contribute to an increase in understanding sustainable management. Additionally, effective scaling-up strategies can contribute to achieving food and nutrition security under climate change in the coming decades.

Materials and Methods

Conceptual framework and literature review and survey

A smallholder farming system is considered a social-ecological system where such a community's livelihood is closely interconnected with natural ecosystems, particularly ecosystem services (provisioning services, such as fruits, vegetables, trees and livestocks). Several factors, including climate factors, put pressure on the social and economic vulnerability of livelihoods. However, the impacts of climate change on livelihood indeed vary across the heterogeneity of social-ecological contexts. Therefore, CSA could be used as a guideline that can be introduced to highland communities to help increase their productivity and income. It will also help reduce the risk from climate change, which is a sustainability challenging in the future. In such highland social-ecological systems, people's livelihoods are closely attached to and mainly dependent on ecosystem services. CSA can be universally applied to enhance sustainable agriculture and food security under climate change.

This review looked at publications from Google Scholar, Scimago Journal Rankings (SJR), Institute for Scientific Information (ISI), Scopus and online databases to filter for climate change adaptation, climate change mitigation, climate-smart agriculture, food security, highland agriculture and food security in the title and keyword fields. CSA case studies were reviewed, especially those related to highland SEA. In total, 88 results were identified from journal articles, textbooks, book chapters, proceedings and the annual reports of international organizations. The inclusion and exclusion criteria of the reviewed papers started from records identified through database searching (n = 128). Some records were excluded (n = 4). Therefore, full-text articles were assessed for eligibility (n = 124) and some full-text articles were excluded (n = 36). As a result, quantitative synthesis (meta-analysis) was included for some of the records (n = 88). For some CSA case studies that included multiple strategies for achieving CSA goals, the similarity was highlighted of keywords, data, results and plans.

The current study surveyed the highland smallholder agriculture system in Mae Chaem district, Chiang Mai province, Northern Thailand. Mae Cheam highland areas still have problems of shifting cultivation and deforestation. High basic problems are diverse and associated with the way of life of the people and communities. The crop area rotation is short, there is intensive farming and soil erosion from corn cropping. Product failure or reduced yield from a natural disaster not only directly affects products, but also food security and income. During June 2019–May 2020 key informant interviews and focus group discussion (FGD) were undertaken accompanied by diverse participatory tools, such as a transect walk and resource mapping, historical timeline, activity calendar and livelihood economy, to help with stratification and to develop the guidelines for 10 strategies in the community livelihood context.

Ethics statements

This study was approved by the Ethics Committee of the Chiang Mai University Research Ethic Committee (Approval no. CMUREC 61/048).

Results and Discussion

Part 1 Literature review example of Climate-Smart Agriculture

Climate change tends to substantially affect smallholders in developing countries where the majority of the population relies on agriculture for their livelihood (Cheeseman, 2016). Extreme events have affected crop yields and resulted in productivity losses of up to USD 84 billion per year. The agriculture sector must transform itself to be far more productive while being simultaneously resilient to the impacts of climate change (Mendelsohn, 2014). A major challenge for agriculture is its environmental footprint and climate change. According to an Intergovernmental Panel on Climate Change report, agriculture is responsible for about 14% of total GHGs emissions. However, this projection can become as high as 30% of total anthropogenic GHGs emissions if deforestation due to the expansion of the agricultural frontier is included (Intergovernmental Panel on Climate Change, 2007). However, current studies suggest that the worst effects of climate change can be greatly reduced if GHGs concentrations can be maintained in the range 450–550 parts per million (ppm). Hence, the climate change mitigation policy should consider maintaining the concentration of CO_2 in the range 450–550 ppm by 2100 (Timilsina, 2008). The same report indicated that field schools have promoted organic farming systems in rice farming and established a seed bank in the community. Other practices such as soil conservation, reforestation, and agroforestry are being used to maintain carbon stocks while increasing crop production (Chandra et al., 2017). A study in Malaysia showed that postharvest management in the supply chain of paddy fields could increase total yield by 311,792 tonne, especially in rural areas, along with prolonging product shelf life and preserving nutrient-rich qualities (Hamzah et al., 2019). Shikuku et al. (2017) reported scenarios that predicted adoption rates for improved livestock feeding among households with improved dairy cows and expect methane emissions intensity decline with the adoption of improved livestock feeding strategies. For example, the projected increase in annual income from USD 728 to USD 968, which represents a 33% increase for farm households by zero purchase cost, from improved feeding and breeds. In addition, estimated yield gaps ranged from 28% to 167% for livestock products and from 16% to 209% for crop products of smallholder farmers (Henderson et al., 2016), as shown in Table 1.

Six participating ASEAN Member States, namely Indonesia, Laos, Myanmar, Philippines, Thailand and Vietnam have accepted CSA under the regional umbrella for food security related initiatives, which include the emerging threats of climate change. In addition, an inclusive resilient and sustainable production base contributes to food and nutrition security and prosperity in the SEA Community. The Thai government initiated a proposal for a Production System Approach for Sustainable Productivity and Enhanced Resilience to Climate Change under the Agriculture, Fisheries, and Forestry towards Food Security in 2009 (ASEAN Ministers of Agriculture and Forestry, 2015). Laos plants specific types of maize (yellow maize and sweet maize), while Vietnamese farmers mainly use their own home-grown seeds and hardly use other inputs, such as fertilizer and insecticide. The current study provided a classification of strategies. ASEAN Ministers of Agriculture and Forestry (2015) reported that CSA practices applied in crop

Table 1 Literature review examples of Climate-Smart Agriculture

Source	Study area	Objective	Methodology/ Data analysis	Results/conclusion/suggestion
Mendelsohn (2014)	Agriculture in Asia	To consider the impact of climate change on crops in Asia.	Ricardian model	The agriculture sector must transform itself to be far more productive while being simultaneously resilient to the impacts of climate change.
Oanh et al. (2018)	Southeast Asia	To consider the emissions from crop residue open/ field burning in SEA	Annual emissions from burning crops	The annual average quantity of crop residue biomass subject to open burning in SEA during 2010–2015 was 152 Gt/year.
Chandra et al. (2018)	Mindanao region of the Philippines	To explore how climate resilience involving smallholder farmers can advance climate-smart farming	Data from field observations, 86 interviews, and 13 FGD	The livelihood outcomes to smallholder farming landscapes strengthen adaptation, mitigation, and food production outcomes.
Rao et al. (2016)	Village Climate Risk in India	Used climate resilient agriculture encompasses incorporating adaptation and resilient practices in agriculture.	Planning, coordination, monitoring and capacity building of the program	The villages improve farm productivity, farm income and livelihoods at the household and village levels. Environmental impacts were assessed on improved soil carbon sequestration and measurements of GHGs emissions
Hamzah et al. (2019)	Malaysia	To examine the relationships between crop yield and nutrition through a food system lens.	Adaptation from a white paper (Climate Change and Variability)	Postharvest management in the supply chain of paddy fields could increase total yield by 311,792 tonne, including sensitive species selection and nutrition. Maintain in some countries to prolong product shelf life and preserve nutrient-rich qualities.
Phungpracha et al. (2016)	Northeast Region of Thailand	To determine the impacts of food acquisition changes on communities	In-depth interviews and household surveys	The lowland subsistence farming community has a higher level of traditional ecosystem knowledge and shows a stronger indication of food security than the upland cash-crop-focused community.

production systems in SEA, ranging from indigenous practices and field-tested crop management measures to knowledge-based options, are already well documented and have proven positive results to enhance climate resilience.

Part 2 Strategy for Climate-Smart Agriculture

Among the agriculture systems in many SEA countries, there are many campaigns to decrease and stop chemical usage and to enact laws to prohibit the import of chemicals (Yadav et al., 2015; Prakash et al., 2018). The agricultural sector must increase production quantitatively and qualitatively to meet the market's needs. This section reviews and identifies CSA in 10 strategies and practices, especially smallholder farming systems, to improve CSA outcomes (Fig. 1).

Climate smart

Current global temperature changes have direct and indirect effects on agricultural production. Higher temperatures may be beneficial to some plants, such as C4 plants or some lateritic species (FAO, 2010; United Nations, 2017). Studies have found that the farmers can utilize past experiences or events that are recorded in agriculture or traditional knowledge, so that if an event happens in one year, the crop species need to be planned and modified in the next year. (Brandt et al., 2017; Mwongera et al., 2017). Farmers should use knowledge of climate change in the past to forecast and plan for the future. Farmers should apply crop activity on their farms, including the planting season and harvesting, to avoid various natural disasters (Limnirankul et al., 2015b). To achieve this situation and reduce the damage caused by climate change, farmers need to be aware of the impact of climate change on agricultural production. Awareness differs between those who do receive and do not receive training. There is an awareness of reducing plant production costs and adaptation to the effects of climate change (Trinh et al., 2018).

Energy smart

Oil usage by tractors, farm equipment and agricultural pumps contributed to 99% of all energy use in agriculture (Mohan, 2018). Intensive tillage leads to increased costs and effects on farms and the environment (Niu et al., 2019). Zero tillage and soil turnover are two energy-saving techniques used in agriculture; reduced soil tillage stimulates arbuscular mycorrhizal fungi, increasing the soil's ability to absorb nutrients and the organic carbon and energy cycles in the soil (Helgason et al., 2010; Hydbom et al., 2017). The use of compacted tillers significantly reduces emissions; depending on the year of study, CO_2 emissions under tillage systems decreased by 7–35% compared to the conventional system (Rutkowska et al., 2018). The case study sections presented here provide information on food waste-to-energy via anaerobic

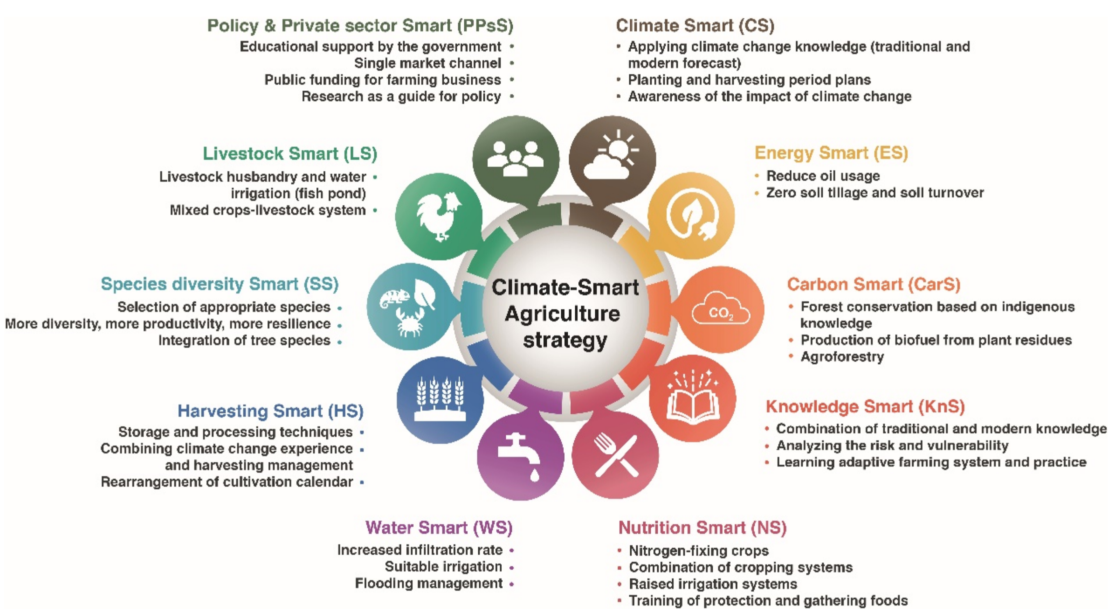

Fig. 1 Climate-Smart Agriculture strategy diagram

digestion systems. For example, a co-digester at a dairy farm for manure and food waste and a co-digester at water resource recovery facilities for wastewater solids and food waste produced 17% water resource recovery (Ghose and Franchetti, 2018). The quantity and commodity value of the energy products would depend on the food waste feedstock quantities from anaerobic digestion of the food waste and could be based on the total amount of food waste sent to the facility, based on a factor of 550 kWh generated per tonne (United States Environmental Protection Agency, 2014).

Carbon smart

Forest management plans and strategies are essential parts of a carbon smart program. In Vietnam, forest conservation is based on indigenous knowledge, such as for agroforestry and traditional medicinal plants (Son et al., 2019). Shifting cultivation system management creates a complex variety of plant species, with carbon sequestration and forest management especially ecosystem services (Nguyen and Nghiem, 2016). One case study reported utilizing the Greater Mekong sub-region for biofuels production regarding carbon balance for different scenarios of bioenergy in five SEA countries (Ranjan and Moholkar, 2013; Ko et al., 2017). Using plant residues as raw material for the production of second-generation biofuels may provide large carbon credits for sustainable agriculture development (Ranjan and Moholkar, 2013). In addition, agroforestry can increase GHGs retention by reducing tillage and reducing the use of chemicals (Wangwacharakul and Bowonwiwat, 1995). Tree-garden management in the Malaysian rain forest used agroforestry to increase fruit production from trees five-fold (Moore et al., 2016). The integration of trees into the rice production landscape enhances farmer and ecosystem resilience to climate change by spreading production on farms and additionally reduces the associated risks from market volatility and crop yields and strengthens resilience regarding pests, diseases and other biological threats (World Agroforestry Centre [ICRAF], 2018).

Knowledge smart

Knowledge management or traditional wisdom could be combined with modern knowledge to support climate change resilience to improve productivity and income (Chandra et al., 2017). The examined CSA practices implemented in Mindanao, the Philippines, showed that Climate-Resiliency Field Schools served as a multi-level institutional platform where farmers can access climate information to improve farm period planning. Likewise, farmers use mapping and an annual agricultural activities schedule in the highland agricultural communities in Mae Chaem district, Chiang Mai province, Northern Thailand to adapt to the climate each year. The communities will jointly analyze the feasibility of the climate to suit the plants and the times of plantings, including scheduling harvesting before storms (Fig. 2). For the protection of rice farms at risk from drought or loss, farmers have learned and adapted rice farms to home garden diversity plant farming to increase rice yield efficiency (Trinh et al., 2018).

Nutrition smart

Nutrition is essential for plant growth; it helps to balance the growth of the plants and saves on the cost of chemicals, particularly nutrients obtained from the nutrient cycles and transmitted through nature (FAO, 2013), as shown in Fig. 3. Many communities grow leguminous plants that can fix

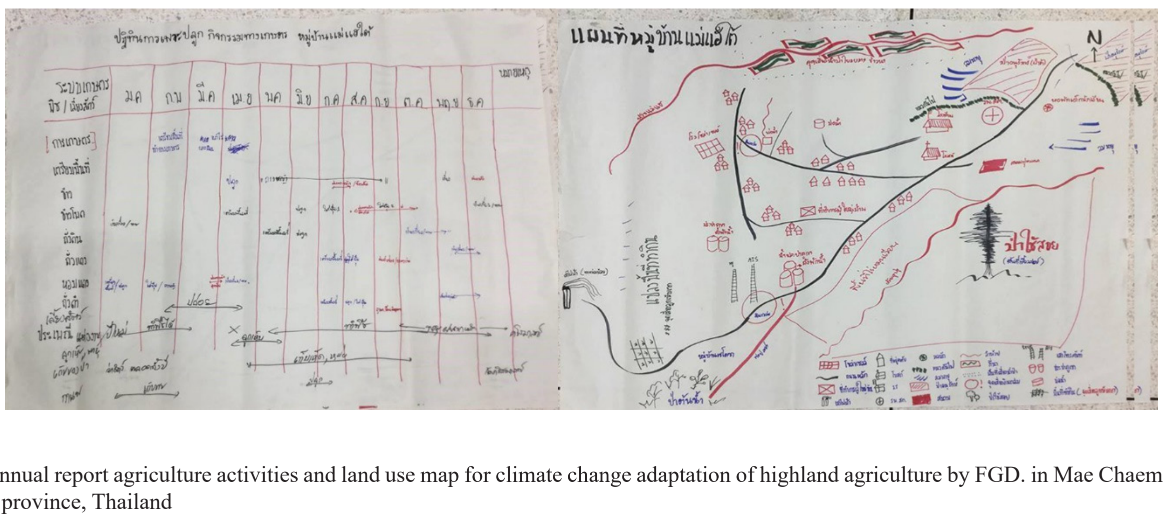

Fig. 2 The annual report agriculture activities and land use map for climate change adaptation of highland agriculture by FGD. in Mae Chaem district, Chiang Mai province, Thailand

Fig. 3 Nitrogen-fixing legume cultivation rotated with other plants decreases usage of chemicals, Mae Chaem district, Chiang Mai province, Thailand

nitrogen, rotated with maize, pumpkin and shallot (Trinh et al., 2018). Small growers are expanding to increase labor power using a combination of cropping systems, where annual and perennial crops are grown (Mohan, 2018). This practice is environmentally safe for both consumers and producers (Calabi-Floody et al., 2018). Raised irrigation systems can be used to protect crops and livestock from loss due to seasonal changes in rainfall and extreme weather events (Fanzo et al., 2018). Farmers should receive training on a variety of topics, including crop protection, food collection and preparedness, as such training is an effective tool for dealing with extreme events (Hochman et al., 2017). Additionally, increasing consumer awareness of nutrition will make nutritious foods more accessible and appealing (Danton and Titus, 2018).

Water smart

Increased forest area impacts many activities relevant to farming such as soil penetrability and microbial communities. An increased infiltration rate reduces liquid outflow causing decreased soil erosion and increased soil penetrability by roots (Bhan and Behera, 2014). In addition, the infiltration rate increased the microorganism population and the numbers of earthworms. Some farmers in Cambodia used sprinkler or drip irrigation to increase water and nutrient-use efficiency (Miyan, 2015; Siderius et al., 2015). The management of excess water (flooding) through water control structures reduces the evaporation of water from the soils, which will help add nutrients to the soils (United Nations, 2019). For Thailand, highland agriculture is managed using ditches (Fig. 4) and fish and other aquatic animals are raised in ponds to provide meat in dry seasons (Fig. 5). The Khok Nong Na model is a new agricultural concept based on the New Theory Agriculture and the Sufficiency Economy philosophy initiated by His Majesty King Bhumibol Adulyadej. The Great Farmers apply the Sufficiency Philosophy in their agricultural activities to help ameliorate the impacts of economic crisis, natural disasters and other unproductive natural conditions (The Chaipattana Foundation, 2012). Under this concept, 30% of land is designated for a pond to store rainwater to supply water to grow crops and raise aquatic animals and plants, 30% is set aside for rice cultivation, 30% is used for growing fruit and vegetables and 10% is set aside for accommodation and livestock. The Khok Nong Na model could solve almost all the problems related to agriculture in Thailand, such as drought and flooding (The Chaipattana Foundation, 2012).

Fig. 4 Highland agriculture water management (ditches) in rainy season in Mae Chaem district, Chiang Mai province, Thailand

Fig. 5 Smart farm aquarium (pond) in Mae Chaem district, Chiang Mai province, Thailand

Harvesting smart

Management can help to improve the performance of the system to grow plants while reducing harvesting costs and increasing profits. Training on safe storage and processing techniques, such as drying, could be provided (Fanzo et al., 2018). A study in Malaysia showed that postharvest management in the supply chain of paddy fields could increase total yield by 311,792 t/year (FAO, 2018; Hamzah et al., 2019). In addition, using different varieties in crop management can increase the maturation growth period (Wang et al., 2018). For Thailand, the Hmong people use past climate change experience to manage harvesting; for example, when a storm occurs during the monsoon, farmers will assist one another in harvesting the produce first (Limnirankul et al., 2015a; Uy et al., 2015). In a case study in the highlands of Thailand shallots were normally cultivated in January and harvested during April–May, when there was a greater risk of damage from hailstorms. Thus, a post-cultivation period in November–March in following years decreased exposure to this risk (Limnirankul et al., 2015b).

Species diversity smart

The selection of plant species appropriate to the local environmental conditions can increase productivity and decrease maintenance costs. For example, planting more than one species can improve the soil for some plants, such as cabbage or cauliflower interplanted with bean family plants will receive increased nitrogen from the beans (Tang et al., 2013). Furthermore, such crop diversity should lead to increased productivity and income. Postharvest management is important for the rice highland area because it affects seasonal variables. Thus, while an extreme event may reduce the rice production, there may be production and income from other crops instead (Salvini et al., 2016). A study in Malaysia showed that postharvest management in the supply chain of paddy fields could increase the total yield by 311,792 t (Hamzah et al., 2019). Wang et al. (2018) reported maize yields could be increased by increasing leaf productivity in the late-growth stage. Postharvest and solar fungicide can reduce the impact of climate change on maize. In addition, varieties and crop management can increase the maturation growth period and enhance leaf productivity of maize and in some countries can prolong product shelf life and preserve nutrient-rich qualities (Fanzo et al., 2018).

Livestock smar

Livestock production plays an essential role in developing countries, especially smallholder farming systems, and is assisting with facing climate change and variability. Asia's meat consumption forecast will increase from 150 million tonne to 224 million tonne by 2050 (Springmann et al., 2016). Livestock in Asia is essential for families and good livestock husbandry helps to reduce costs and the risk of food shortages and so support food security. Fishponds are not only used for livestock husbandry in households but also for water irrigation (Rao et al., 2016). The environment of the fishpond and home garden plants leads to high ecosystem services and biodiversity (Kansuntisukmongkol, 2017). Climate change poses a threat to livestock production due to its impacts on crop quality, forage, water availability, animal and dairy production, cattle disease, animal reproduction and biodiversity (FAO, 2018). On the other hand, mixed crop-livestock systems can increase efficiency by increasing production while using fewer resources and by increasing climate variability tolerance (Rojas-Downing et al., 2017).

Policy and private sector smart

The government's land use policy includes forest utilization management for sustainable outcomes, such as a food utilization forest zone, conservation zone, wildlife zone or community forest. As a result, the highland communities have increased food accessibility in the forest. The government must educate the stakeholders to enhance their market chain to sell forest products. A highland workshop on organic farming resulted in high produce values for competition in city markets (Son et al., 2019). Furthermore, finding channels to improve the ease of transport to direct consumers is also an important strategy and to provide direct selling to consumers by not using an intermediary. Event activities can bring together farmer group participants and government advisors. In addition, loan supports or public funding for smallholder farming can reduce the burden of debt management and contract farming. (Kansuntisukmongkol, 2017; Bateman and Balmford, 2018). Research related to policy is an integral part of compiling a database for government use to be applied as guidance, such as research on environmental policy or measuring the quality of various products (Thow et al., 2018; Eanes et al., 2019).

Part 3 Keyword summary used in this overlap search related to Climate-Smart Agriculture and remaining challenges

The Intergovernmental Panel on Climate Change reported that the changing in climate pattern is influenced by the GHG effect, which heats up the earth's surface and raises atmosphere temperature, whether due to natural causes or as a result of human activities (Intergovernmental Panel on Climate Change, 2007, 2014). Contextual analysis on rural GHG outflows for Cambodia, Laos and Vietnam indicated high pesticide use on vegetables (Chun et al., 2016). Additionally, the lack of information about valuable and harmful insects led to the utilization of more pesticides, compared to farmers who were aware of the risks in using pesticides (Schreinemachers et al., 2011). Native plant species in Vietnam may be successful in increasing productivity consistent with the current local climate but perhaps they cannot adapt to future climate changes as well as other species. Most farmers will also rely on knowledge and experience rather than dealing with violent events (Campbell et al., 2014; Limnirankul et al., 2015b; Son et al., 2019). Improving the farm system can lead to increased income and farmer resilience (Jalota et al., 2013; Son et al., 2019).

Keyword overlap of climate change, Climate-Smart Agriculture and food security

CSA is a sustainable development strategy in the agricultural sector. However, a short-term increase in crop production is often achieved at the expense of long-term system resilience (Intergovernmental Panel on Climate Change, 2007; Mwongera et al., 2017). Studies on farmers' preferences for CSA technologies are marked by some commonalities as well as differences according to their socio-economic characteristics and rainfall zones (Saj et al., 2017). In addition, there must be consideration of the culture, and livelihoods suitable in a society (Rao et al., 2016; Wiebelt et al., 2013). Food insecurity affects low-income farmers who do not have access to food (Praneetvatakul et al., 2001). Agricultural productivity is affected by climate change (Brandt et al., 2017; Walls et al., 2019). Adopting genetic hybrids for resilience to climate change, agroforestry and mixed farming all depends on having the available areas (Rao et al., 2016; Fanzo et al., 2018). Trees are a source of food, especially fruits that are healthy and enable the forest community to adequately supply food by trading without reducing the forest asset (van Noordwijk et al., 2014; Dung and Sharma, 2017; Rao et al., 2016).

Overlap of climate change adaptation and mitigation, food security and highland agriculture

Most people in the highlands still lack new knowledge and practices. Farms are often used for crop production but often suffer from low yields (Charnsungnern and Tantanasarit, 2017). Reverting to shorter rotations, intensive farming and soil erosion from corn crops are some responses (Wangpakapattanawong et al., 2010). Periods associated with some years of no crop return increase debt and force the household to open up new farmland by clearing forest (Pitakpongjaroen and Wiboonpongse, 2015), with important repercussions on agriculture, livestock and the loss of organisms in highland areas (Phungpracha et al., 2016). Food insecurity or the risk of food insecurity may be associated with a rotation system, as crop failure or a reduction in yield from a natural disaster may directly affect production and lead to food insecurity and loss of income (Kyeyune and Turner, 2016).

Disadvantages of Climate-Smart Agriculture

CSA has been applied in many areas around the world to improve small farming systems and achieve its three main goals. The first goal is to increase productivity and income. However, in some cases, it has been shown that CSA applications might lead to some lost income, as when farmers find that their income or profit increases, some farmers may increase their arable land, resulting in the inability to control production under the CSA practices, causing the area to deteriorate from intensive agriculture. The second CSA goal is the resilience of food systems and livelihoods. Mechanical marketing is in the private sector domain and it may be too difficult for smallholders to gain a foothold and some marketing control. If farmers increase their productivity but are unable to sell the produce or are forced to manage costs by underselling, then they often incur losses and increased debt (Schmit and Gómez, 2011; Chandra et al., 2018). However, land ownership and income restrictions are most likely to reduce the ability to access CSA techniques to the poorest and most vulnerable groups of society (Schaafsma et al., 2019). Furthermore, the financial return, the required implementation costs and the probability of losing the invested money should also be considered. Some critical information can help farmers to re-evaluate their investment decisions (Ng'ang'a et al., 2021). Nonetheless, there is still an information gap regarding the profitability of undertaking such an investment, as this is key in determining the sustainability of CSA practices. On this basis, Ng'ang'a et al. (2021) undertook a detailed analysis on the costs and benefits of adopting CSA practices on household livelihoods. Such findings are critical to promoting and scaling up the adoption of CSA practices by smallholder farmers and can serve as a basis for formulating appropriate guidelines and policies for supporting CSA practices (Azadi et al., 2021). Such analysis can provide farmers with the necessary information to determine the duration required to achieve a break-even point. Since farmers are the ones that bear the investment cost and directly receive the economic benefits of adopting CSA practices, the analysis presented should be from the farmer's viewpoint and not the public's (Makate et al., 2019).

The final goal of CSA is the reduction and removal of GHGs from farms. Although agroforestry and conservation agriculture can decrease GHGs, farmers may lack income while waiting to use the forest in short-term farming areas (Dawson et al., 2014; Henderson et al., 2016).

Issues and challenges of Climate-Smart Agriculture

The challenges in facing climate change have increased in the agricultural sector around the world. In the highlands of SEA it is imperative to find strategies and improvements to support risk management, especially smallholders farming. Small-hold farmer communities around the world need to acquire technical knowledge to improve their agricultural capacity. Academics and researchers can participate in community processes top provide suggestions and conduct workshops. In addition, the system is dynamic due to the ongoing risks associated with climate change in the future. Therefore, risk-handling and coping capacity need to be assessed under the livelihood performance context and climate change trends to design such adaptation. Subsequently, the appropriate strategies could be identified to suit each social-ecological sub-system to achieve CSA. Government officials and researchers should develop methodologies in learning and use these to coach farmers. The farmers can apply to farm activity situations under climate change. In particular, traditional knowledge and risk management actions that have been handed down traditionally over many generations combined with modern knowledge and technology can be applied to manage agricultural systems facing climate change. Achieving CSA will lead farmers and younger people to adapt to the future and mitigate the effects of climate change on their livelihood and sustainability and on their communities. There are important roles and actions required to achieve CSA goals. Governments must adopt cross-country policy and support data management regarding plant breeding and technology. Non-government players must create learning platforms for knowledge exchange (via a constructivist learning approach). Institutional and research input should a CSA network and provide collaboration to seminars and conferences. The private sectors can create a campaign to promote CSA via social media. Finally, youth groups and clubs should be formed start advocating for CSA.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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