A PLATFORM FOR DIGITIZING AND SCALING UP OPTIONS WITH SMALL FARMS INTO SDG: A REVIEW

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ABSTRACT

Small farms are successfully managing household and natural resources to meet the needs of household members for food, feed, fiber, fuels, which are a part of local and national economic systems. These achievements was supported by an array of relationships and actions, organized by communities at the local, national and international level, that emphasized high quantity of outputs from a given agroecosystem using array of new crop and livestock varieties and associated agricultural technologies. The actions produced positive and negative consequences on local communities and environments, both on and off-site. These consequences, together with climate change and variability, prompted local communities, Government and private organizations to further develop better policies, technologies and innovations. The emerging Agricultural Information and Communication Technologies (AgICTs) provide platforms and opportunities for small farms, policy makers and scientists to systemically design and evaluate new agricultural technologies prioring to their actual implementations in the real farm and nonfarm settings to manage limited resources. It concludes that the substantial contributions of AgICTs to achieve SDGs must be at the core of the fundamental change needed in policy and education systems if we are to achieve a transformation of household, natural and agricultural resource management policy and practices to a sustainable and desirable common future.

Keywords: Systems approaches, interactions, farm and non-farm activities

INTRODUCTION

Asia-Pacific is a diverse region, so there are ecologically and ethnically differing types of agricultural systems, which are household activities to produce raw materials for household consumption process and sale the surplus to markets. In particular, Thailand is home to approximately six million small farms (SFs) households (NSO, 2013) and one of the world's few major agricultural exporters in various commodities, i.e., rice, cassava, sugar, sweet corn, and feeding high quality products to more than four times her own population from mainly rainfed and less intensive agricultural systems than its neighbors (Falvey, 2000). In 2011, agricultural systems were also contributed about 17.32% to the total national Greenhouse Gases emissions or 52.93 $MtCO_2eq$., 38.02 and 14.91 $MtCO_2eq$. from CH_4 and N_2O emissions, respectively. The report also shown CO_2 emissions of 42.70 $MtCO_2eq$. from LULUCF or Land Use, Land-Use Change, and Forestry sector (ONEP, 2015). To cope with climate change, during the 70th Session of the United Nations General Assembly New York on 29 September 2015, Thai Prime Minister of the Kingdom of Thailand stated the shared responsibility to ensure the outcome of the COP 21 (Conference of the Parties 21) and reaffirmed the National's commitment under the INDCs (Intended Nationally Determined Contributions) to reduce Thai's greenhouse gas emissions between 20 and 25% by the year 2030 from 2005 baseline.

The establishment of Intergovernmental Panel on Climate Change (IPCC) in 1988 have been marked by numerous advances in knowledge and publications on relationships of agriculture and climate change, i.e., its impacts, society's policy and capacity to adapt and mitigate. Therefore, agricultural systems in the world and in Thailand need some kinds of revolution to efficiently utilize limited resources, based on good agricultural practice and process to produce high quality outputs with the aim to maintain sustainability of the ecosystems (Llewellyn, 2018).

A just climate change policy, either for adaptation or mitigation, must be geared towards SFs. It is very crucial and important to the next agricultural transformations for several reasons: first, protecting the ecosystems and vulnerable people from climate change impacts, second, protecting people from disruptions of transformation, and finally, enhancing the process of envisioning and implementing an equitable post-carbon society. Serious climate policy must focus more on the near-term and on feasibility. It must consider the full range of options, even though some are uncomfortable and freighted with risk (*Xu et al*., 2018).

For Thailand, the challenges under changes are to utilize AgICTs in order to keep the level of diversity which are still common in Thai agricultural systems, and that a central component of future development is the small farmers as an integral component of the whole society (Falvey, 2000). The Next Agricultural Revolution (NAR) must be geared towards People-Ecol-Techno-centric include: co-developing of innovations and AgICT (Agricultural Information and Communication Technologies) that are based on SFs needs and resources; considering emergent properties of the whole system; localizing innovations, team working and networking model with peer-supporting process, lowering dependency on external inputs, valuing multi-cultures and interdependent in a collaborative world, equipping with multi-way and online communication tools and platforms, demanding for quality and quantity, localizing markets that ecological-oriented, SDGs-readiness, small farm matter as learning platform, lowering debts, and better social and ecosystem health situations locally and globally.

WHAT ARE OPTIONS FOR SMALL FARMS?

A system approach to address the question, under climate change, was allow users to co-develop and co-evaluate AgICTs, i.e., simulation models and its associated resource databases, to study the interactions of ecosystems and options of agricultural systems than to carry out the real experiments on the systems themselves (ICRISAT, 1984; Uehara, 1998; Marohn *et al*., 2013). Specifically, SFs should be able to use these AgICTs, co-developed with various research teams and implemented by government agencies, to address a set of farm-specific and short-term questions at the farm level, for example;

1. What crop/livestock options should I plant/raise on this land with the approval of my neighbor and with my own natural and agricultural resources (especially the fragile *soil ecosystems*) as much as possible?
2. What crop/livestock options should I plant/raise in this season and how to precisely manage resources for community and ecosystems, i.e. reduce greenhouse gas emissions?

Agricultural systems are human activities and practices that implement options to modify natural ecosystems in order to produce raw materials to meet demands from multi-users. Therefore, it is logical to develop multi-user AgICTs consist of predictive simulation models, based on scientific understandings, and databases, based on field and remote sensing survey methods. Users can learn and collaborate to evaluate options with AgICTs as a team of end users, next users, and research team users (Fig. 1). SFs, stakeholders and users of these AgICTs could collectively apply better alternative options to collaboratively manage agricultural and natural resources to meet both local and national objectives. Specifically, these

AgICTs must also allow users and SFs to localize their efforts to make collective decisions based on digitalized data sets to decarbonize towards sustainable development goals.

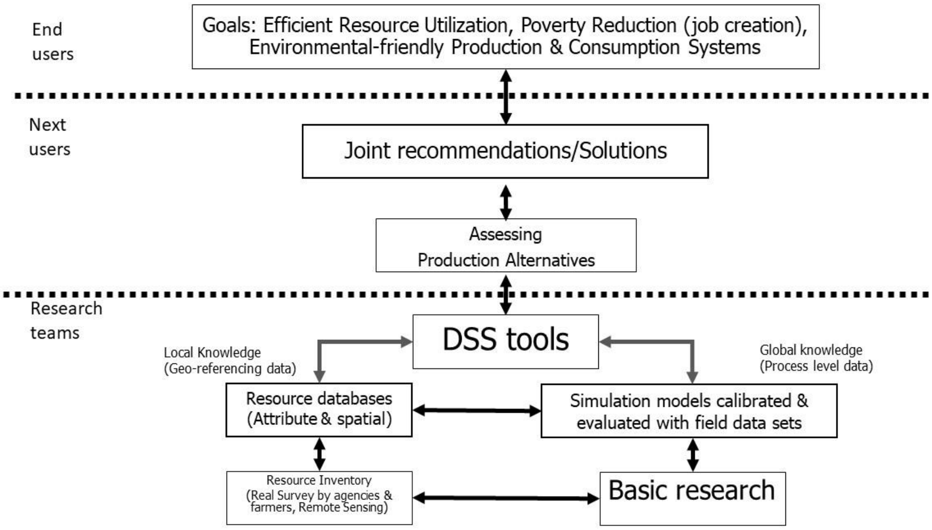

Fig. 1. A transformational platform to collectively make decisions to scale-up decarbonized options based on digitalized local and global data sets into Sustainable Development Goals (SDGs).

Source: modified from Uehara (1998); Jintrawet *et al.* (2012); Marohn *et al.* (2013).

Localizing digitalization for decarbonization

Digitalization efforts focus on the transformation of manual resource survey data sets into digital resource databases and the transformation of scientific understandings from laboratories, field experiments and scientifitc publictions into simulation and statistical models. The digital resource databases and the models are the essential components of a Decision Support System (DSS tool), a form of AgICTs, for evaluation of options to decarbonize of agricultural systems under climate change situations. DSS tool was developed to make decisions under uncertainty and to address 'what-if?' and un-structured questions (Tian, 2007). The demands and application of AgICTs and associated data sets are to make better decisions to decarbonize by allocating resources, spatially and seasonally (Janssen *et al*., 2017). These group of AgICTs were developed to address the issue of 'doing the right thing in the right place at the right time'. In turn, these DSS tools can be used to assess the alternative resource utilization options for a given province, with numerous type of SFs, in a given crop growing season could also be conducted to support collaborative planning and engagement into sustainable development, specifically to decarbonize and maintain natural resources.

The digitalization of national resource databases, partially related to decarbonization practices, in Thailand has been routinely carried out by various implementing agencies, for example; soil database by Land Deveopment Department (LDD, 2018), weather and climate database by Thailand Meteorological Department (TMD, 2018), current landuse types and related agricultural statistics database by the Office of Agricultural Economic (OAE, 2018), rice and other major crop planted area maps by the Geo-Informatics and Space Technology Development Agency (Public Organization) (GISTDA, 2018), and agricultural census report and database by the National Statistical Office (NSO, 2013). In addition, various research groups are also providing data services that can be accessed and incorporated to decarbonize studies, for example, seasonal climate forecast data sets can be accessed and linked with simulation models for seasonal rice yield forecast 3-4 months in advance (RCCES, 2018). Additional policy and joint efforts are urgently needed to incorporate variables related to greenhouse gas emission and sequestration by various agricultural and food consumption systems at various levels, i.e., plot, farm, urbanized and building zone, district, province, as well as various economy sectors, i.e., energy, industry, agricultural, waste, and LULUC.

The transformation of scientific understandings from laboratories, field experiments and scientifitc publictions into simulation and statistical models, with predictive capabilities, and associated field experimental data sets for model calibration and evaluation. These models has been developed since 1980s (Williams *et al*., 1989; Supit *et al*., 1994; de Wit *et al*., 2019; Bouman *et al.*, 1996; McCown *et al*., 1996; Brisson *et al*., 1998; Jones *et al*., 2003; Arnold *et al*., 2012), revised and applied to various situations ranging from crop varietal evaluation, watershed management to climate change issues. Most models could be further improved to incorporate scientific understanding about the relationships of agricultural systems and key GHGs, include carbondioxide, methane and nitrous oxide. With good investment on local data collection, these models can be calibrated and evaluated to provide synthesis of options to decarbonize of various crop production systems.

Within The Thailand Research Fund (TRF), Precision Agriculture (dubbed called TRF-PA network and a continuation of TRF-DSS) was defined as agricultural systems that farmers or growers utilize ICTs to make better decisions to allocate natural and agricultural resources in order to improve quality and quantity of farm input-process-output, above and belowground ecosystems, while reducing the impact of agriculture on the environment. The development of PA cases in the network started in October 2015, with the coordinating unit at Chiang Mai University. Using peer-support approach, the network has provided a platform for researchers to interact with farmers in order to co-develop ICTs technologies for site-specific resource management, mainly water and soil nutrient resources (Attanandana *et al*., 2007; Jintrawet *et al*., 2012). However, more efforts must be taken to handle decarbonize objective into the network and research projects to scientifically co-develop decarbonized prototypes of various systems and sectors (Berthet and Hickey, 2018).

SFs and policy makers can co-learn to adopt suitable agricultural technologies using these DSS tools by shifting from scanning and data retrieval to more qualitative steps, such as interpretation, decision-making and implementation for a creative and human-centered activity (Keller and von der Gracht, 2014) into localizing decarbonization of agricultural systems and sustainable development goals.

Localizing decarbonization of agricultural systems

This is a joint effort of stakeholders and requird DSS tools and political will to implement and engagement with local groups. Decarbonization of current agricultural systems should simply be managed by SFs as multipurpose agricultural production systems in a changing environment. DSS tools can be collaboratively used to address questions, at the strategic and the landscape-field levels, related to cost of, how much carbon can be removed or sequestrated, where and when to decarbonize?

At the strategic policy level, DSS tools should allow users to evaluate decarbonized options of agricultural sector include improved short-term practices to enhance soils as a long-term carbon sink project such as a voluntary action plan ‘4 per 1000 Initiative’ (UNFCCC, COP21; Soussana *et al*., 2017). Technologies and materials for reducing crop-related emissions and reducing and capturing livestock emissions can also be enhanced through cultivation techniques that convert atmospheric CO_2 to carbon-based compounds in the soil systems, while also reducing erosion of sloping agricultural lands and the need for fertilizers and providing other benefits. Plant breeding programs that offer new varieties of plants with long roots or other characteristics favoring carbon sequestration can also enhanced agricultural sinks; and shifts in consumption patterns of consumers toward less carbon-intensive foods (Huber, 2018). Nguyen *et al*. (2018) also reported that rice, maize and sugarcane residue open field burning was major emitters and alternative solutions must be developed with local communities as well as Government regulations. Transformation of some chemical farming into organic farming systems could reduce GHG emissions by 0.049%, as well as mitigate methane and nitrous oxide emissions from the current shares of transportation of organic farming output across most states

(Squalli and Adamkiewicz, 2018).

At the landscape level, with watershed management approach, various opportunities to reduce emissions (Cai and Zhang, 2018) and enhance carbon storage using DSS tools in the LULUCF sector (Yang *et al*., 2016). These options can focus on maintaining or adding forests and slowing conversion to settlement or agriculture. Existing forests can be managed for greater carbon sequestration through fertilization, irrigation, switching to fast-growing planting stock, increasing intervals between harvests, decreasing harvest intensity, and increasing forest density (McKinley *et al*., 2011).

At the farm level, decarbonization can be carried out on site by SFs with supported from community and policy. The objective is very clear, i.e., to reduce level GHG by 50% in every decade (Rockström *et al*. 2017). In Thailand case, with approximately six million SFs, with a joint effort to decarbonize, by 2030 Thailand could cut 50% of GHGs from agriculture sector (that is 25 MtCO_2eq. based on 2011 inventory).

At the field and plot level, N_2O emissions can be reduced through improved management of nitrogen fertilizer use, such as better tailoring the quantity and timing of applications, improving fertilizer formulations, and applying fertilizer directly to roots. Fertilizer use can also be reduced through precision agriculture, which uses advanced technology such as sensors and data analysis to fine-tune the application of farm inputs to field conditions. Also, CH_4 emission from flood rice fields and wetlands can also be reduced by using AWD and other infrastructure investment (NAMAFacility, 2018; Tian *et al*., 2018). In the Chao Phraya river basin in central Thailand, in the field trials, farmers that applied Cost Reduction Operating Principles (CROP) practices reduced costs by 6–36% (±17%) and increased net income by 21–131% (±79%) when compared with the same season in the previous year (Stuart *et al.,* 2018). Precision agriculture can also reduce fuel requirements by reducing the areas that receive agricultural inputs and the number of applications (Gebbers and Adamchuk, 2010). Equipment cooperatives and other local mechanisms to share equipment could help overcome cost barriers for individual farms (Shannon *et al*., 2018). These efforts will bring about sustainable livelihoods during and after localized decarbonization process.

The effort of decarbonization of agricultural sector, as a part of the whole society, can be jointly implemented on four fronts, namely; a) decarbonizing the production of electricity, b) undertaking massive electrification (to increase reliance on clean electricity) and, where not possible, switching to cleaner fuels, c) improving efficiency and reducing waste in all sectors (building, transpor tand agriculture), and d) preserving and increasing natural carbon sinks through improved management of forests and other vegetation and soils (Fay *et al*., 2015). These effort could be efficiently and locally implemented with the support of communities to collectively making decision.

Localizing decision making for decarbonization

Decision making is a process to allocate limited agricultural and natural resources to meet objectives of producing raw materials for food, feed, fiber, and fuels for socity and ecosystems with minimum GHG emissions. These process required a shift of thinking and methods by integrating both bottom-up and top-down approaches with DSS tools (Mimura, *et al*., 2014), for sustainable soil management (Srivastava *et al*., 2016), and for the creation of cost-effective and equitable adaptation plans at the local level (Girard, 2015). DSS tools can be used as tools to enhance communication between the both user groups and collectively implement lerning and adaptation of suitable decarbonize options for a given situation at a given watershed or administrative boundary (Bilali and Allahyari, 2018). This approach of decision making is based primarily and hinge on the strengths and weaknesses of local communities to observe, analyse, innovate, connect, organize collective action and become part of wider coalitions (van Noordwijk, 2017).

The bottom-up approach required that stakeholders gain understandings of the impact of global climate change on local agricultural systems and the range of adaptation and mitigation that could be locally implemented to cope with the changing climate. DSS tools can be used to progressively engage stakeholders to dialogue and explore possible consequences of options on future ecolocial and economic development, by considering a large number of factors. The output of this task should be one or several options for decarbonize, with associated assumptions, i.e. social, regulatory, economic, ecological and environmental. SFs and local communities can probably make decision to allocate resources to adopt one or two plausible decarbonize options at the plot, field, and farm level, however, some options needs supports from the top-down approach.

The top-down approach normally chooses several climate models (known as General Circulation Models: GCMs), projections and scenarios that simulated the response of the climate systems to a scenarios of future emission of GHGs concentration and aerosals (IPCC, 2013). Then the projection data sets were linked to simulation model for studies on adaptation and mitigation options of various economic sectors and ecosystems in various geographic regions. However, to yield collective actions to decarbonize, good communication about the risks and distributional impacts are needed and very critical (Fay *et al*., 2015). In

Thailand, the bioeconomy have been identified as a key component in the 20-year National Strategy of Thailand towards sustainability transition (Royal Gazette, 2018). The strategy was designed to transform Thai society to a pathway of renewable, bio-based, circular and green resources (BCG), with various short and long-term positive outcome and impacts on ecological, socio-economic and environmental dimensions.

Bridging between the two approaches required skills in climate change communication with SFs and local communities to prepare to adapt and mitigate into decarbonization and SDGs. In Thailand case, the challenge now are to preserve the quality of agricultural land, as well as that of water resources. In 1990s, greater use of fertiliser was needed to preserve soil quality (Moncharoen *et al*., 2001). Now, increasingly intensive use of fertilizers and pesticides could become a threat to the environment, but until recently there has been only anecdotal evidence that this has been the case (Poapongsakorn, 2006). With higher land availability per capita and lower crop yields than in most neighbouring countries, Thailand must address the challenge of producing more with more careful use of natural and agricultural resources with a practice platform for fully engaged communities into the next green revolution.

A SCALING-UP PLATFORM

We are proposing a platform for systemic scaling up innovation adaptation options that promote active participation and engagement by local farmers and Government agencies (Fig. 2.), depicting activities of generic rice production systems from the beginning to the harvesting in Thailand. In these proposed scaling up platform, two layers of integrating data flows should be operate to gain better understandings of the interactions between the farmers, government workers and allow generation of minimum data sets of both farm and non-farm activities. The inner circle (green arrows) of the platform allows farmers to input data and information about his/her farm and non-farm activities from planting to harvesting of a crop in a specific plot of her/his farm. Farmers must be compensated for their participation based on the amount of quality data entered onto the system. The outer circle (blue arrows) of the platform retrieve data and information of each plot with associate attribute data about farm and non-farm activities and organize into a minimum data set for simulation models. The data sets from both the green and the blue arrows will support our cooperation to improve the model's performance in simulating adaptation options.

This platform is built around the following three sentences: "The traditional and current platform is good if we could collect and convert manual data into digital databases. It is even better if we use the databases to gain understandings and predict behaviors and dynamics of agricultural systems and climate system. It is excellent if we could collaboratively making decisions to handle risks and main our ecosystems.”

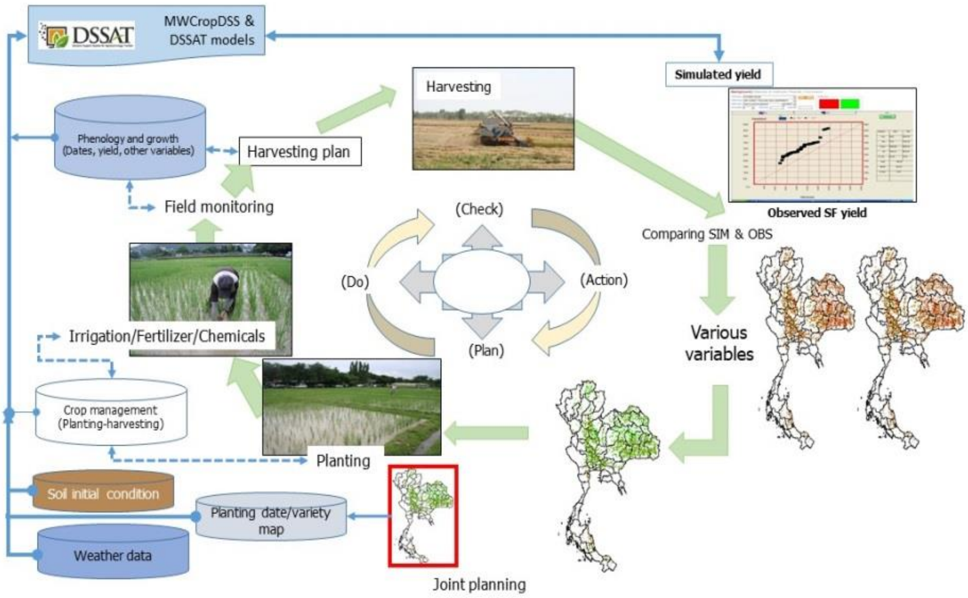

Fig. 2. A systemic and innovative approach to maintain and improve rice productivity under climate change scenarios.

OPPORTUNITIES

Next generation of 3D-technologies, i.e., Decarbonization, Digitalization and Decision Making, research and development programs for climate change adaptation and climate change mitigation must take advantage of these technologies and opportunities to remove institutional and required data sets to decarbonize. Azhoni *et al.* (2017) reported barriers that need to be removed especially with regarding to accessibility to data and information, which were shaped by systemic bureaucracies and cultural attitudes. Approaching barriers with an approach that systemic, contextually interconnected cultural, geographical and political underlying factors enriches the understanding of adaptation enablers, thereby contributing to achieving a better adapted society.

Educational and organization cultural systems that must learn and listen to the voice and perspective of their intended beneficiaries, i.e., SFs (Schurman, 2018). Future of SFs under changes depends of measures to stimulate and integrate the rural farm and nonfarm activities and industries that aims to providing jobs for those leaving farming, a favorable rural investment climate for all member of the rural community (Leturque and Wiggins, 2010).

A shift of society's understanding of agroecosystem-rich (that is not resource-rich ecosystems) as part of a sustainable earth and society that is distributed and responsive model of governing energy transitions. Chilvers *et al*. (2018) have developed and demonstrated a new perspective on 'participation' in socio-technical change with specific reference to energy system transitions. Notions of participation, inclusion and societal engagement have become central to realizing socio-technical transitions that are more democratic, sustainable, socially shaped, responsible, just, and responsive to public values and human needs. Such responsiveness to ecologies of diverse and continually emergent public meanings, values and actions is crucial to building more socially sustainable, inclusive, responsible and just socio-technical (energy) transitions.

SFs must be equally and fully engaged in next generation of agricultural technologies that take advantage of ICTs and transform into the climate change-ready, professionally and interdependently, member of society. We must viewed climate change, a non-monetary value of a resource, as opportunity to increase cooperation across the board, which was not moderated by individual differences, thus providing some tentative evidence for the generality of the present findings (Bastian *et al*., 2019).

CONCLUSION

Small farms are growing in numbers worldwide and are a major producer of raw materials for livelihoods that support both local and international economy. AgICTs will provide supports for SFs in different climatic and edaphic conditions to gain btter understanding of our relationships with the Earth climate system, subsequently enhance our capacity to predict and handle both threats and opportunities. Transformation in educational systems in learning and developing new 3D-technologies are needed and must integrate SFs as an integral part of and a key actor of the whole learning experience. In sum, we can see the path forward to achieve SDGs by 2030, which need a series of collective efforts and dynamic collaboration to jointly establish systems of policy and practice for the management of natural and agricultural resources into a sustainable and desirable common future.

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