Social practices required for the recovery of cassava waste for heat generation in Thailand

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Abstract

Thailand is a dominant supplier of cassava to world markets, supplying around 67% of the global market, resulting in abundant cassava waste. However, farmers typically discard this waste in cassava fields, and thus it is underutilised as an energy resource. In addition, Thailand's domestic cassava-based bioethanol plants depend on imported coal to produce heat. To address this challenge, this research investigated the potential for the collection and recovery of cassava waste from farms. Semi-structured interviews were conducted with Thai cassava farmers. Social practice theory was applied to evaluate the effects of cassava waste collection on Thai cassava farmers' current agricultural practices. Three Thai cassava agricultural activities— land preparation, fertilization application and waste management—would be impacted by this new strategy. The connections between each of these potentially affected activities has been discussed and, ultimately, cassava waste collection by Thai cassava growers was proposed as a new practice. This study concluded that the enhanced use of cassava waste for the production of heat and power could potentially help Thailand meet its renewable energy targets in future.

Key words Cassava waste, Farming Practices, Thailand

1. **Introduction**

In 2009, Thailand's Department of Alternative Energy Development and Efficiency (DEDE) enacted a new policy in its report, *The Renewable and Alternative Energy Development Plan for 25 Percent in 10 Years* - AEDP 2012-2022 – (Sutabutr , 2012) which mandates an increase in domestic alternative energy production to 25% of national energy resources by 2021 (DEDE, 2012)

This plan is subdivided into three foci: electricity, heat and biofuel generation. Thai policy has set the renewable energy capacity target for electricity generation at 24,956 GWh (3,353 ktoe) by 2021, which represents about 10% of projected electricity consumption for that year and set its renewable heat generation target at 9,335 ktoe.

Specifically, the Thai government has set a biofuel production target to replace 44% of oil consumption (or approximately 39.97 million litres per day) by 2021. Consequently, this requirement has led to significant growth in the Thai biofuel industry over the last decade (DEDE, 2012). Thailand has an abundance and variety of agricultural residues, such as bagasse, rice husk, straw, wood and cassava waste together with biomass and agricultural residues. These have been harnessed as an energy source through combustion, gasification, pyrolysis and anaerobic digestion to generate domestic electricity and heat. Utilizing biomass residues and agricultural wastes for power generation is an option to increase the use of biomass energy and help achieve the government's energy targets. Such action could also potentially reduce Thailand's fossil fuel consumption, energy dependence, and greenhouse gas emissions.

This study explores the potential impacts of a change in the use of cassava waste on Thai cassava farmers' current practices. The research question being investigated is how the production and collection of cassava waste as a new agricultural practice affects cassava farmers and their current farming practices, as well the environment.

Thailand is an agricultural nation with abundant biomass resources. Cassava (*Manihot esculenta Crantz.*), commonly known as 'tapioca,' is one of Thailand's four main agricultural products, along with rice husk, bagasse and palm oil. Cassava is an agro-industrial crop with a very well-developed industry and market in Thailand, and it is considered one of Thailand's most important economic crops with over 31 million tons produced in 2016, from less than 1.5 million hectares of plantations (OAE 2017). Thailand is the second largest producer of cassava in the world, behind Nigeria (Arthey et al 2018). Thailand is ranked as the world's largest cassava products exporter and supplies around 67% of the global market (TIR 2017). In 2016, Thailand exported over 4.26 million tons of cassava based products (TIR 2017).

The primary parts of the cassava plant include the leaf, stem, rhizome and root. The most commonly used part of the plant is the root, which is primarily employed for industrial and commercial purposes and as a feedstock for bioethanol production. Cassava stems and rhizomes are not typically used, and thus usually become waste. By weight, the cassava plant comprises top/leaves 5%, stem 11%, rhizome 8% and root 76% (DEDE 2006). After harvest, farmers typically pile cassava waste in their fields, either leaving it to dry or burning it. Over 31 million tons of cassava is produced annually, and based on the figures above, this leads to almost 9.3 million tons of waste (stem and rhizome). The average energy content for the cassava stem/rhizome is 18.4 MJ kg^{-1}(DEDE, 2009). Nationwide therefore, cassava residues (stems and rhizomes) could generate a significant amount of heat and power depending on the type and efficiency of the power plant utilised. Ideally, cassava waste could be used in power plants or industries, particularly those in central and northeast Thailand. Combined heat and power would be an ideal choice for industries requiring a constant supply of heat and power.

2. **Cassava waste**

Most cassava in Thailand is grown in the east, northeast and central areas of Thailand in about 45 provinces comprising approximately 8.2 million rais (OAE, 2013).

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Typically, 20% of cassava stem residue is collected post-harvest for use as planting stock, 29% is employed as fertilizer and nearly 10% is lost during harvest (OAE, 2013). Similarly, the rhizomes of the cassava plant are not employed for any practical purpose, as their hard shells contain a high percentage of silica, making them difficult to break and ignite (Demirbas, 2004). Farmers normally dispose of cassava rhizomes by ploughing it into the soil (23%) or burning it in situ (66%). However, collection and combustion of the 66% of cassava rhizomes burned in Thai fields (2.89 million tonnes) could potentially generate up to 146.77MW of electricity annually (DEDE, 2009).

Studies of cassava waste utilization (Sangpetch and Sangkasaad, 2000; Arjharn 2001) found that cassava waste combustion has great potential in Thailand to displace fossil fuels for heat and electricity generation and shows promise for further development as an energy source. Sengpetch (2000) discussed a Thai experiment in which dried cassava root chips were tested in a mobile boiler. Six metric tonnes of dried cassava root chips were combusted, generating 2MW of electrical power per hour from 28 tonnes of steam.

The study demonstrated the favourable combustion characteristics of dried cassava root chips and showed that due to low sulphur content (<0.1%) the resulting flue gases were relatively clean. Sengpetch also found that due to its lower price and similar calorific value, cassava rhizomes could replace dried cassava root chips as a fuel source, and showed that dried cassava chips cost approximately 5 times more than rice husks. Cassava rhizomes and stems contain relatively low alkali and chlorine content (0.122%) (FINPRO, 2002) and low nitrogen, sulphur and ash content (1.27 %, <0.1 % and 4.05% on dry weight basis, respectively). The nitrogen, sulphur, carbon and ash contents of fossil fuels directly affect greenhouse gas emissions, corrosion levels and ash deposition (Demirbas, 2004). Cassava waste, when cofired with coal in cassava-based bioethanol plants, could potentially reduce sulphur dioxide (SO_2) and nitrogen dioxide (NO_x) emissions of these plants. Arjharn (2001) found that the energy production of cassava rhizomes via gasification is appropriate for rural communities, and that farmers faced challenges in the collection and transportation of cassava waste from their fields.

3. Key elements for adoption of new farming practices

A number of international studies have focused on farmers' adoption of new technologies and practices. Factors deemed to be relevant include: farmers' characteristics and perspectives (Griffin and Frongrillo, 2003), behaviours (Murray-Prior, 1998), motivations (Ostwald et al, 2013; Greiner et al., 2009) and attitudes (Edwards-Jones, 2007; Garforth et al, 2013). In addition, several studies specifically address farmers' adoption of new agricultural biomass collection practices for use as renewable energy resources. Paulrud and Laitila (2010) investigated the willingness of Swedish farmers to grow biomass crops based on the acreage of energy crop cultivation and relative to income levels and subsidies. This research employed the choice experiment (CE) method, a standard approach to studying the individual behaviour within the marketing, transportation research and environmental economics disciplines. Paulrud and Laitla (2010) focused on agricultural holdings (private firms and limited liability companies) with arable land acreage greater than 10 hectares within one of four regions. A sample of 2000 farmers was randomly selected from the 2005 Swedish Farm Register and was compiled by Statistics Sweden.

The outcomes of the study conducted by Paulrud and Laitla(2010) showed that the farmers who chose to grow bioethanol fuel crops based their decision on those crops that maximize utility, the size of which depends not only on expected net income but also on crop characteristics. The results also revealed that farm characteristics such as leased land, rented land and farming type had an insignificant effect on a farmer's willingness to grow bioethanol fuel crops.

In another study Jensen et al. (2007) examined the willingness of US farmers in Tennessee to grow switch grass for bioethanol fuel production. A total of 15,002 surveys were sent to a statewide random sample of 19,684 farmers. Researchers employed a two-limit Tobit model to isolate the effects of various farm and producer characteristics on the proportion of farmland that farmers would be willing to convert. Results showed that while the majority of respondents had not heard of growing switchgrass for energy production, nearly 30% would be willing to grow it if it were profitable. In general, they were concerned that technical assistance would be required and that markets were not yet sufficiently developed. In addition, younger farmers with higher levels of educational attainment and off-farm incomes were willing to convert a greater proportion of farmland. Moreover, farm size and the use of leased farmland correlated negatively with the willingness to convert hectares to switchgrass production. In addition, while erosion issues did not appear to convert their lands for growing switchgrass, desire to provide wildlife habitat did.

These two studies identify a number of variables that can be expected to affect adoption of new waste management practices. These include farmer characteristics (e.g. age, farm size, background and expertise), effective utilization of agricultural current resources (e.g. machinery or technical assistance), and awareness of effects on soil health (e.g. erosion and condition).

Both studies discussed above employed a variable approach to identifying the key factors governing farmer adoption of new waste management practices. In contrast, Convery et al. (2012) adopted a more qualitative approach to studying the willingness of UK farmers to switch land uses from food production to biomass production in Cumbria. Interview and focus group data were produced and analysed using grounded theory. Specifically, researchers employed the constant comparison method, in which each item is compared with the rest of the data to establish and refine analytical categories. The authors found that there is a reluctance to change from current farming methods to preserve both the iconic character of the region and the family, and age structure of the farming community.

A key finding in Convery et al's work concerned the need to understand farmers' characteristics and existing practices when new practices are introduced. Current agricultural practices varied depending on farmers' background, behaviour, geography, perspectives and culture. Farmers also differed in their concerns regarding the potential impact of a new practice on current practices. These differences could affect farmers' decisions in adopting new waste management practices.

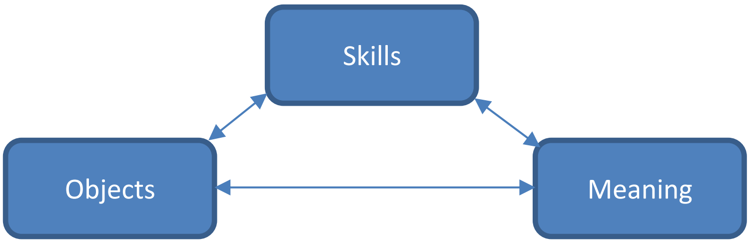
Taken together, these studies, in particular Convery et al.'s (2012) research, suggest the need to move beyond general agricultural demographic and economic factors to consider social, cultural and attitudinal factors. A key premise of this research is that the success of a cassava biomass collection programme for use in bioethanol plant fuel production would depend in part on its effects on current agricultural practices and on the support that farmers receive. While many studies suggest that a variety of types of agricultural wastes could be employed for biofuel production, it is important to note that little research exists regarding the social practices surrounding the use of agricultural waste in general or of cassava farming in particular. Specifically, no research exists on the potential effects the introduction of cassava waste collection practices could have on current agricultural practices.

A key objective in this research is to provide a 'snapshot' of the current practices of Thai cassava farmers to anticipate and support the implementation of a new cassava waste collection program for the production of heat and power in bioethanol plants.

4. Research methodology on adapting social practice theory

This research frames farming as a succession of many interrelated practices. This study also extends the social practice theory (Shove et al., 2012) approach to a consideration of what might occur in the Thai agricultural community if the new cassava waste practice is introduced. To do this, the study focuses on the relationship between current agricultural practices and the envisioned new practice; social practice theory (specifically the three elements of material, competence and meaning) is used to model both current practices and the new practice and to reflect on the potential relationship between them.

Figure 1 illustrates some of the elements highlighted by the analysis of cassava farming as a social practice. In this case, the basic claim of social practice theory with respect to agriculture is that successful farming depends on the relationships between these elements. Objects include agricultural tools, fertilizers, soil health and plant stock. Skills include farmers' skills and expertise of how to use the material elements. Meaning refers to the hopes and expectations to which farmers ascribe their success in growing cassava.



Skills: using agricultural tools, driving tractor skill, expertise of current practice, expertise of soil condition and cassava, time management and waste disposal.
Objects: Agricultural tools, fertilizers, herbicides, pesticides, labourers, soil, stems, cassava waste, chemicals and tractors.
Meaning: lifestyle, feeding family, family trade, accomplishment, expertise, pride, improved standard of living, improved soil quality and yield, environmental benefits.

Figure 1: Elements of Thai cassava farming (adapted from Shove et al., 2012)

One of the main contributions of social practice theory to this study is it affords the opportunity to examine 1) the potential of new practices to break existing links and 2) the need to establish new links for a new practice to thrive. According to this theory, the success of a new practice depends on the links between elements of existing practices and the new one. However, the introduction of new methods and expertise could break the links within a current practice, making way for new approaches and understanding which could be carried over from the current practice (Shove et al., 2012). Shove et al. (2012) also noted that innovation in practices can leave abandoned and disconnected elements behind. Applied to the study of cassava farming, social practice theory calls on the researcher to identify the various material objects, skills and meanings that make up cassava farming.

In this study, social practice theory is employed to study how Thai cassava farmers' current practices may be affected by the adoption of new practices, and to investigate how current expertise, skills and resources might be utilized in the new practice.

Typically, farmers leave cassava waste in their fields and plough it back into the soil, but it could be collected and used to generate heat and power in cassava-based bioethanol plant. This new practice, cassava waste collection, could influence farmers' current cassava waste management practices.

In this study data was collected using semi-structured interviews. This method can provide insight into how and why farmers might adopt a new practice and change their current practices. In addition, this approach is appropriate for studies that explore farmers' perspectives and current practices. The qualitative method allows researchers to identify potential commonalities in farmer characteristics and patterns in how farmers implement cassava farming practices.

Semi-structured interviews were conducted with 25 cassava farmers. They were selected from a list of potential study participants of cassava farmers within a fifty-kilometer radius of three separate cassava-based bioethanol plants. Twenty farmers from five regions in Thailand agreed to participate in the study and were interviewed on either an individual basis or in group. The interviews were conducted between 25 June and 13 July 2013.

The cassava farmer interviews were designed to identify farmers' characteristics and discuss current practices. Social practice theory provided an analytical framework for these interviews and was used to help determine the effects of implementing the new cassava waste collection practice into existing agricultural practices. Questions discussed in the interview sessions are provided in the appendix 1.

5. Data analysis

Creswell's qualitative data analysis process was adapted and employed in this study. Figure 2 summarizes the qualitative data analysis process in a simplified flow diagram.

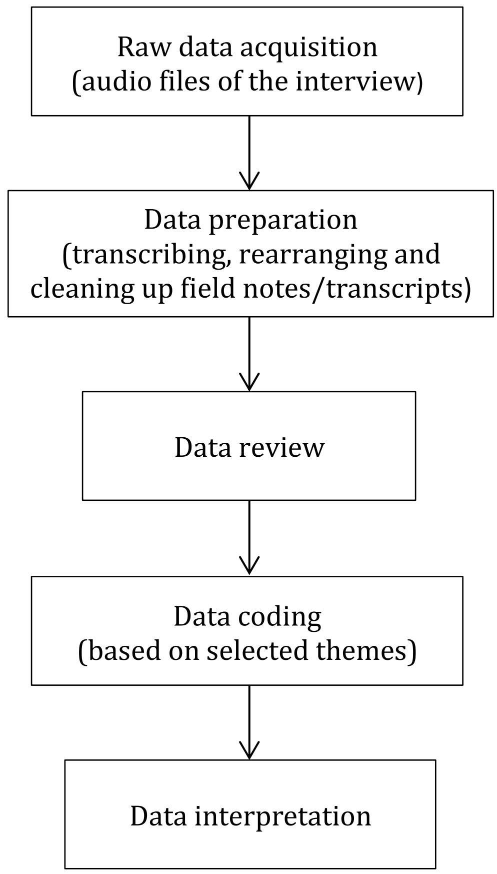


Figure 2: Qualitative data analysis process (adapted from Creswell, 2009)

All of the interviews were transcribed verbatim and their content was analysed using NVivo 10 qualitative data analysis software. Data analysis began with the identification of current agricultural practices with respect to three aforementioned elements of social practice theory: objects, skills and meaning (Figure 1). Based on this analysis, farmers were categorized into three groups according to farm type and agricultural practice; small full-time, small part-time and large (see section 5.1 for descriptions). Each of the eight current cassava farming practices (land preparation, planting, fertilization application, disease control, weed management, harvesting, waste management and transportation) were analysed to determine the connection between the three key elements (material, competence and meanings) of social theory practice. Then, those current practices were examined and re-analysed around the question of how the introduction of a new cassava waste collection practice might affect each existing cassava farming practice. After a review of all the interview transcripts, broad current practice categories were identified for use in data analysis and interpretation.

5.1 Characteristics and categorisation of cassava farmers

Generally, Thai cassava farms are categorized into three groups based on farm size: small, medium and large-scale farms.

A social practice analysis of Thai farmers suggests that cassava farmers can be categorised further into three groups based on their economic characteristics and agricultural practices: part-time small-scale farmers, full-time small-scale farmers and large-scale farmers. Further detail about these categories is given below. These categories differ from a Thai classification, which is based exclusively on farm size and distinguishes between large- and small-scale farmers (figure 3). The vast majority of cassava production in Thailand is carried out by smallholder farmers operating on farms of < 4 hectares (Arthey et al 2018). Whilst cassava is grown as a cash crop by farmers, in most instances it does not provide the sole source of livelihood for the household.

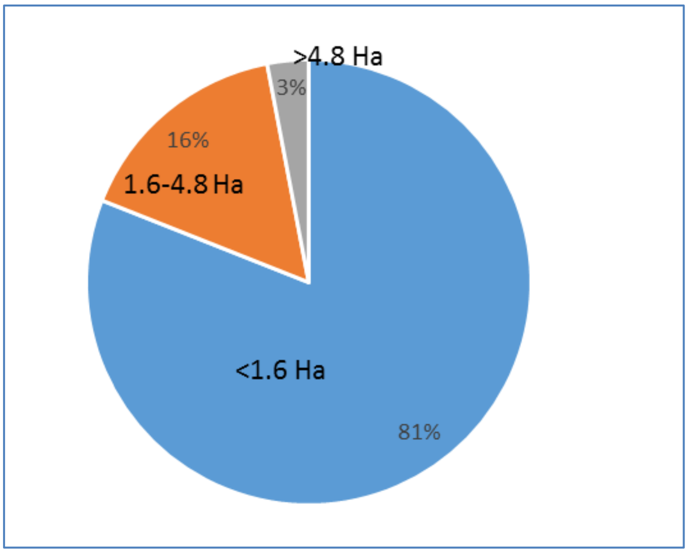


Figure 3: Farm size area in Thailand (Arthey et al 2018)

An initial analysis of the data highlighted significant differences in the three elements of social practice theory (materials, skills and meanings) that full- and part-time small farmers bring to their work. The proposed three-way classification aids in exploring challenges facing each group and provides a more realistic framework from which to evaluate the potential effects of this new practice on Thai farmers.

5.1.1 Part-time small scale farmers

The farmers in this category typically retain their farms and grow cassava as a part time job; most of them own their land and some rent land for growing cassava as a small family business. These farmers invest their factory salaries in their cassava farms and earn additional income from cassava production. Some cassava farmers have also become small investors in cassava businesses. Most part-time small-scale farmers hire labourers to farm because the farmers do not have sufficient time and enough family members. However, cassava farming practices and techniques are still dictated by the farmers themselves, not by hired contractors or labourers. The size of part-time small farmers' cassava farms varies depending on the owners' background and income.

5.1.2 Full-time small-scale farmers

Most full-time small farmers are more sophisticated in terms of farming expertise, and have developed competences that help them face contingencies that might occur on their farms. Their main income is from agriculture. Both community and government support contribute to the expertise and competence of farmers in this group, but, at the same time, these farmers often face labour shortages. In addition, government support is critical, and the Thai government provides loans and pesticide supplies to help full-time farmers. However, access to tools and equipment is often limited. Labour shortages are a challenge for this group, but because they own their land and can manage the work by themselves, these shortages are not as much of an obstacle as they generally are for part-time farmers. These farms are usually no larger than 3.2 hectares.

5.1.3 Large-scale farmers

Large-scale farmers are big investors in the cassava business. Their cassava plantations are usually larger than 50 rais (1 rai = 0.16 hectare). These farmers usually have a full complement of agricultural equipment (both large machines and small tools) and extensive expertise in cassava farming. Most of these farmers are large investors who typically employ their own full-time experienced labourers.

5.2 Current practices in Thai cassava production

An analysis of the interviews for all three types of farmers revealed eight main activities, or sub-practices, in cassava farming. The key practices in cassava production are well known, and include: land preparation, planting, fertilization application, weed management, disease control, harvesting, waste management and transportation.

However, these practices vary according to the characteristics of farm type, culture, soil conditions, expertise and technology.

As illustrated in Figure 4, these activities (sub-practices) may potentially be affected by cassava waste collection practices. According to social practice theory, a new practice may weaken or break the links between the meaning, materials and skills of the current practice.

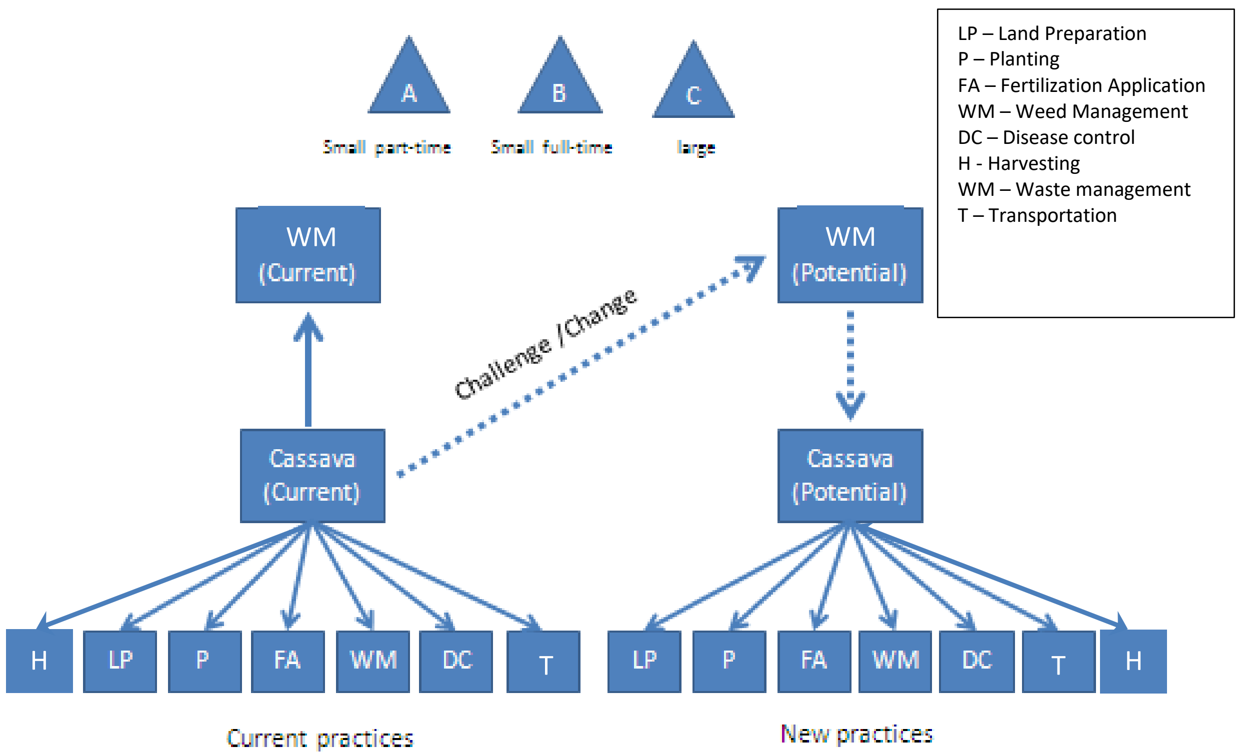


Figure 4: Framework for current and new practices

5.3 Prospective analysis: The potential effects of the collection and use of cassava waste for heat and power generation on existing farming practices

This section focuses on the relationship between current farming practices, the incorporation of a new practice (cassava waste collection) and the considerations that this practice may require. In order for this practice to succeed, current agricultural practices may have to be modified to accommodate cassava waste collection. Thus far, this study has established that eight activities are involved in current cassava growing practices (see previous section), three of which (land preparation, fertilization and waste management) would most likely be affected by the collection of cassava waste. Based on this analysis, the remaining five activities, planting, weed management, diseases control, harvesting and transportation, are not likely to be affected and therefore will not be assessed in this section. Each of the three activities affected is examined with the aim of identifying which aspects of these activities may be affected by the collection of cassava waste and the possible consequences for current cassava farming practices. The discussion, in turn, provides a basis to identify potential challenges that the introduction of cassava waste collection may pose for farmers in order to better address these challenges.

These findings contribute to the focus of the research and demonstrate that the effect of cassava waste collection on current farming practices can be modeled using social practice theory. According to social practice theory, the introduction of a new practice could affect the links between the meanings, objects and skills that constitute the current practice. Similarly, the success of the new practice would depend on the introduction of new links between the elements of the current practice and the new one (Figure 4). If new links are not established, the new practice may achieve only limited success or fail altogether. With this in mind, social practice theory offers a way to analyse the conditions for the successful uptake of innovations, such as the use of cassava waste for production of heat and power in bioethanol plants.

In the following discussion, each of the three potentially affected activities will be analysed in order to identify possible connections between current farming practices and collection of cassava waste. By assessing the relationships between cassava waste collection and current cassava growing practices, potentially negative aspects and obstacles to the implementation of this new practice will be identified. The likely obstacles for each category of farmers will also be highlighted, such as the challenges involved with securing the necessary equipment for the new practice given limited resources. This analysis will provide a basis to consider the feasibility of the new practice for the different groups of farmers included in this study. This will, in turn, establish the potential of the new practice and the approach that could be taken for successful implementation.

5.3.1 Land preparation

Social practice theory can facilitate an understanding of how land preparation is carried out by farmers and how this practice could be affected by cassava waste collection. The materials for land preparation include cultivation tools and materials, such as tractors, hoes, disks, manure and soil. Land preparation involves clearing all non-used fields and improving soil conditions prior to planting the next crop. In terms of expertise and skill, an understanding of soil conditions, the expertise in operating a tractor and plough and the ability to harrow and farrow are all necessary for land preparation.

The potential relationship between land preparation and cassava waste collection practices is illustrated in Fig. 5. As indicated in the figure, the components of current agricultural practices that might be affected include soil condition, ploughing technique/skill and clearing unused fields (harrowing). Many farmers believe that cassava waste collection could affect soil quality (material), i.e. soil could become denser or thicker if cassava wastes are removed. Incorporation of cassava waste improves soil structure and condition, making the soil more porous, which may result in higher productivity (Figure 1 – "meaning"). In this way, removing cassava waste could decrease land productivity, thereby reducing yields and thus the quantities of waste to be collected. Additional ploughing or changing of ploughing techniques (Figure 1 "skill") may then be required in order to maintain soil conditions when cassava waste collection practices are adopted. For example, increased ploughing with a 3-5-disk plough or 5-7 disk plough may be necessary to improve soil conditions or applying manure may be needed to increase soil fertility. Therefore, this practice may require more work and time in land preparation.

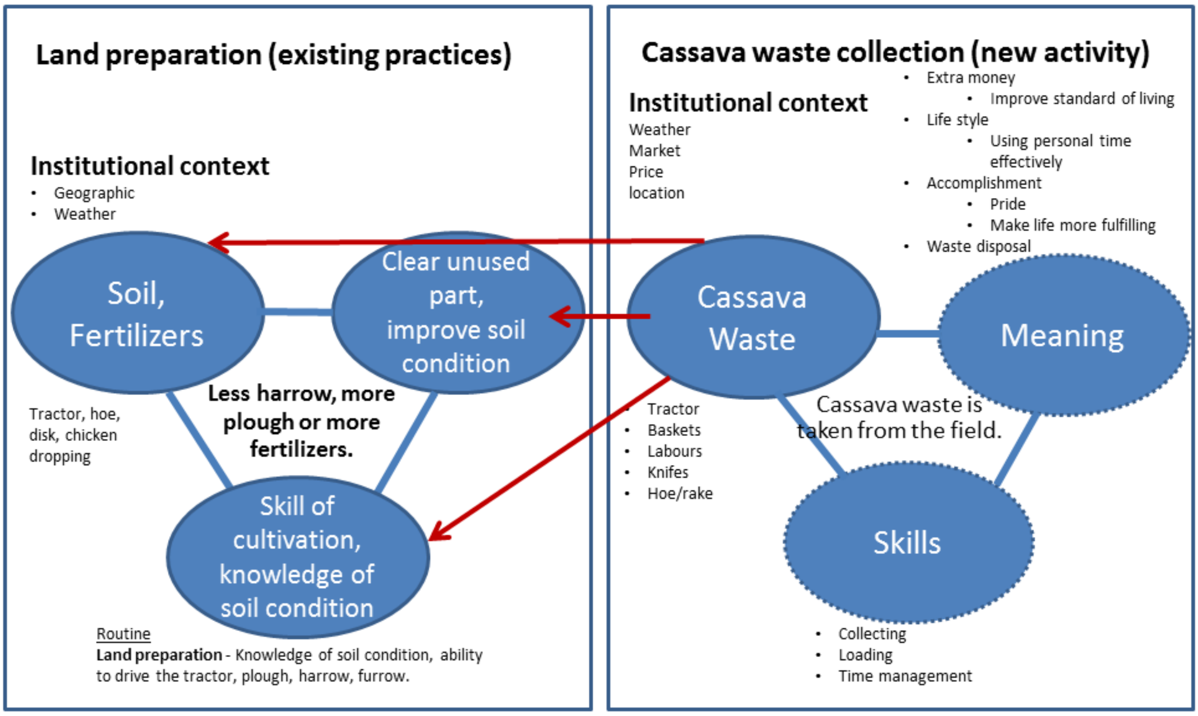


Figure 5: Connections between land preparation and cassava waste collection practices

Another possible effect concerns efficiency. In preparing the land, prior to ploughing cassava farmers must remove any residual cassava waste a by harrowing. But by removing the cassava waste for production of heat and power, famers would require less time for harrowing, as the new practice already involves clearing the fields. This practice could save time if farmers no longer had to clear the land themselves.

Comparing the effect of cassava waste collection on land preparation practices across different groups of farmers, the analysis suggests that the introduction of cassava waste collection may have a smaller impact on land preparation for full-time small farmers than for other groups. This is because these farmers typically farm smaller plots of land and are independent and thus more flexible. Some full-time small and large-scale farmers assert that cassava waste acts as a fertilizer and plough the cassava waste into the soil to improve soil quality. The collection of cassava waste is directly at odds with this practice and suggests that these farmers might resist the new practice or require additional education and support to embrace it. In addition, the adoption of this new method could expand expertise in land preparation and change the conception of cassava residue from waste to productive resource. In particular, the farmers that currently plough waste into the soil are generally unaware of the potential for using cassava waste as a biofuel source. By collecting and selling their cassava waste, farmers could be more inclined to treat this waste as a resource, thereby becoming more aware of alternative options.

As this discussion suggests, more ploughing and greater applications of manure could be options for farmers who seek to improve soil quality after the cassava waste collection practice is introduced. The same skills and expertise in land preparation that farmers already possess could still be applied. However, a change in ploughing techniques may also be necessary in order to avoid excess ploughing and other related work after the new practice is adopted. In addition, cassava waste collection could have an impact on land preparation for all groups of farmers depending on farm soil type, expertise and how fields are maintained.

5.3.2 Fertilization application

According to these findings, some farmers believe that removing cassava waste from fields may adversely affects soil conditions and fertility. If one accepts this view, a major impact of cassava waste collection on fertilization application would be soil nutrient losses that could lead to reductions in plant vigor and yield. Differences exist in fertilization application practices for each group, which impacts this activity. Expertise in and understanding of various fertilizers and cassava cultivars could potentially be important for farmers with respect to the introduction of cassava waste collection.

Fig. 6 illustrates that new fertilizer formulas or types, new NPK ratings/values and additional fertilizer applications might be required to maintain soil nutrition given cassava waste removal. This could require greater investments for farmers to maintain soil nutrition, but might also lead to a higher cassava yields. At the same time, the introduction of this new practice would not require learning new skills or employing additional tools or equipment for fertilizer application. However, familiarity with fertilizer application methods and an understanding of cassava cultivars might be important for farmers in addressing problems arising from cassava waste removal. Notwithstanding, there is a dearth of literature that discusses evidence of the effects of cassava waste removal on farmers or agriculture, so it is difficult to ascertain if or how this practice would have an effect on cassava yields. Moreover, farmers hold conflicting views as to the utility of cassava waste as a fertilizer, and little evidence exists to support this point, questioning the validity of this argument.

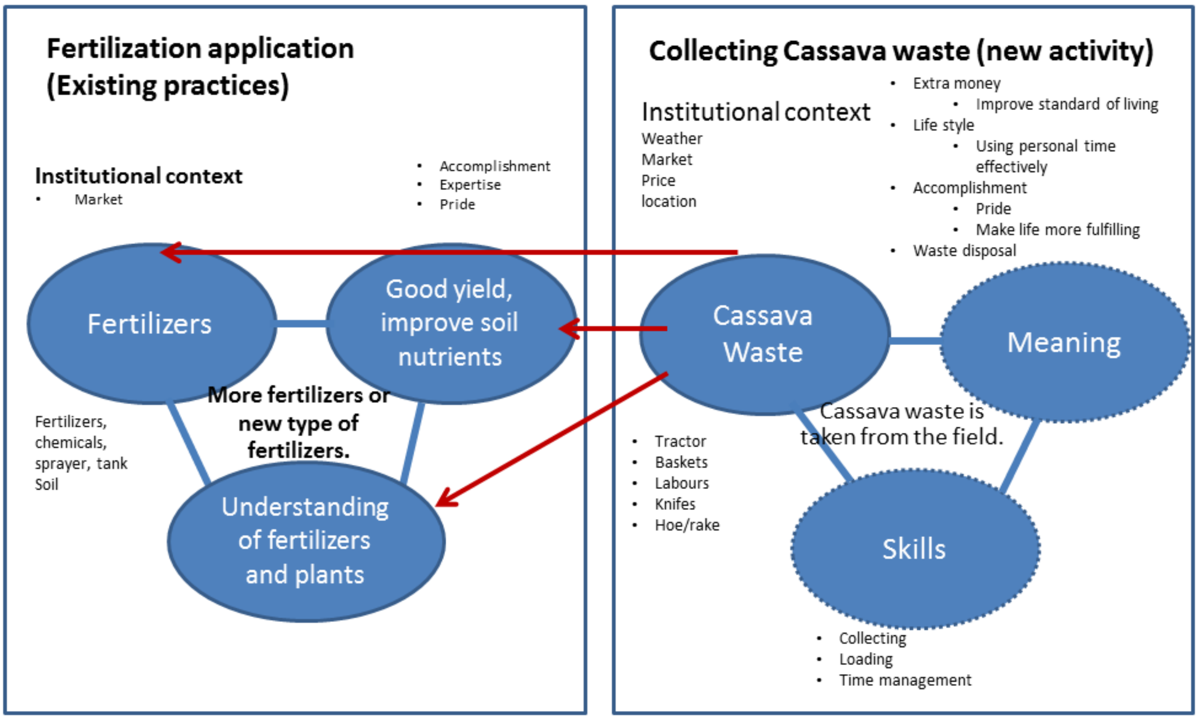


Figure 6: Connections between fertilization application and cassava waste collection practice

In terms of the anticipated effect of this new practice on fertilization application practices across types of farmers, the analysis suggests that implementation could affect the fertilization practices of all farmers. However, it could have a particularly significant effect on large-scale farmers. Due to their large land holdings, farm maintenance is often challenging, which has consequences for soil fertility. Large scale farmers do not generally apply large quantities of fertilizer, but rather apply fertilizer only when necessary or to specific productive areas that are near resources (i.e. pond, canal) or exhibit good soil conditions. Thus, farmers in this group typically do not apply fertilizers to their entire farms because this is cost-prohibitive. In areas where fertilizer is not applied, waste collection could lead to a lower cassava yield. Not changing or adapting fertilizer formulation can cause low yields of cassava especially in large scale farms, which incurs potentially large costs for extra fertilizer and poor crops. This could be a huge loss for these farmers if additional fertilizers do not increase farm productivity. Due to the relatively larger size of farms in this group, farmers typically focus on yield quantity rather than quality.

In contrast, most full-time small farmers carefully maintain their fields. This group typically has a high level of agricultural expertise and understanding of fertilization application. Their fertilization application practices are dependent upon finances, i.e. if income increases additional fertilizer may be purchased. Farmers in this group usually attempt to find the right balance of fertilization method and fertilizer type to maximize cassava yield, as they own relatively smaller farms. Thus, full-time small farmers generally apply greater amounts of fertilizer than other farmers. This practice typically results in richer soil, which can produce higher yields, which in turn allows for greater quantities of cassava to be farmed and later used as waste. Removing cassava waste breaks this cycle, arguably resulting in less productive soils that produce less waste to be collected. Therefore, this effect could also be an indirect influence of new fertilization application practices.

Finally, the analysis does not suggest any significant impacts on fertilization application practices for part-time small farmers. These farmers typically do not consider fertilization application important, as cassava waste is not regarded as a priority. Generally speaking, the data suggest that farmers in this group typically do not properly maintain their fields, and practice only the most basic fertilization methods due to constraints of time and labour.

Overall, fertilization application methods will impact the new cassava waste collection practice, but the different approaches taken to fertilization application by the farmers in the various groups and how they maintain their cassava farms will determine the success of this new practice. In addition to differences in the methods of fertilization application practiced by each group, a farmer's financial situation is another factor in how fertilization application. Applying incorrect amounts or types of fertilizers could lead to increased costs, which is detrimental to lower-income farmers. Therefore, expertise in fertilization application needs to be reviewed. The differences between the groups of farmers, such as free time for maintenance and current knowledge of agricultural practices, need to be assessed to enable farmers to learn new techniques of how to fertilise or improve their soil when cassava waste is taken out from the cassava farms. Their previous fertilizer formulation may need to be updated in order to become suitable for the new practice.

5.3.3 Waste management

According to this analysis, the majority of farmers dispose of cassava waste through burning and ploughing. Only a few of the interviewed farmers had experience with collecting waste for sale. The most significant factors affecting Thai cassava farmers' current cassava waste management practices are time, cost and technology. In this case, cassava waste collection could be a novel means for farmers to dispose of field waste in addition to their existing waste management practices. The connection between both practices and the effect of the new practice on waste management are shown in Fig. 7.

Fig 7 indicates that cassava waste collection could affect time and labour expenditures in cassava waste management practices. With respect to waste management, farmers' typical concerns include determining the most effective, efficient and inexpensive methods to dispose of cassava waste. The introduction of this new practice may change farmers' perspectives on waste management, and they may decide that collection of cassava waste could both be profitable and provide a means to dispose of field waste. In this case, collecting cassava waste could increase farm income, even after they account for the additional time investment involved in collection.

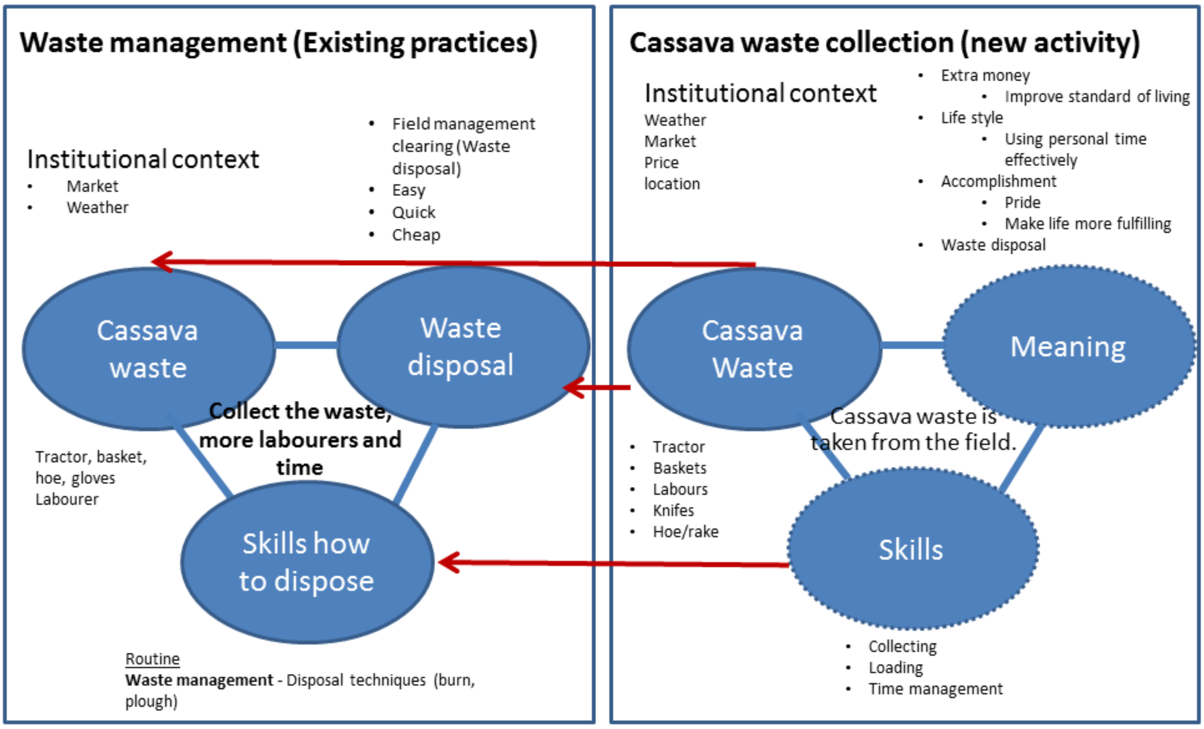


Figure 7: Connections between waste management and cassava waste collection practices

According to the three key elements of social practice theory, the meaning element of current waste management practice would be affected when collection of cassava waste is introduced. The meanings of cassava waste collection include: clearing out unused parts, time consuming and profit. As the new practice could result in more efficient management of time and resources, farmers could produce higher cassava yields in shorter periods, thereby increasing profits. This in turn could raise their standard of living and ability to make land improvements. Furthermore, this increase in productivity could bring farmers a greater sense of achievement and a renewed purpose and pride in their trade. The skill and material elements of current waste management could influence the collection of cassava waste practices as they could employ the existing tools, machinery and knowledge. Existing agricultural knowledge could be expanded as farmers become aware of the benefits of cassava waste collection, adding to their previous expertise. Farmers understand that cassava waste must be removed to prepare for the next crop, and current removal practices include gathering and burning waste or using tractors to crush and plough waste into the soil. However, until farmers learn about cassava waste collection practices, they will be unaware of an effective way to dispose of the waste, expand their expertise and adapt their skills.

In terms of the anticipated effect of the new collection practice on existing waste management methods across categories of farmers, the study found that time and labour constraints are the main obstacles to cassava waste collection. This finding is especially significant for part-time small farmers. Due to their lack of labourers, introducing the new collection practice would mean collecting waste themselves. However, these farmers typically do not have the time to do so. However, if the financial returns were great enough, small farmers could hire labourers to collect waste. Waste transport would typically pose few challenges, as most of the farmers in this group own small tractors and trucks, they could use to move waste to buyers.

For full-time small farmers, waste disposal varies according to farm size, level of expertise and background; current (sub-) practices include: burning, ploughing and collecting cassava waste. As a result, these farmers would not need to learn additional skills to adopt the new practice, and extra income earned from selling cassava waste could potentially improve their quality of life. The most important priority for farmers in this group is to maximize farm returns; thus, large incentives exist for collecting and selling cassava waste. For those farmers with access to transportation, tractors could be used to collect and transport cassava waste to buyers. However, some farmers in this group would need to hire transportation, which could increase expenses. Therefore, extra costs incurred from hiring trucks or labourers could deter farmers in this group from adopting the new practice. However, full-time small farmers are typically amenable to making additional income, provided they have spare time. This new practice could be another way to increase income or allocate time effectively.

With respect to large-scale farmers, their farms produce large amounts of cassava waste. However, farmers in this group face the same challenges as those in part-time small farmer group, namely shortages of time and labour. Even though large-scale farmers have access to equipment and can afford to hire labourers, they often do not have adequate time to collect cassava waste from their land. The majority of large-scale farmers dispose of waste through ploughing, as they assert this is the most effective method. Therefore, the introduction of the new collection practice may face obstacles as farmers in this group considers time more important than income generated from cassava waste collection, especially as their current practice is already deemed effective.

According to the findings, it is apparent that in terms of waste management, full-time small farmers may be the most affected by adopting cassava waste collection. Full-time small farmers have the greatest potential to adopt this new practice, as they have relatively few time constraints and are typically amenable to earning additional income. Furthermore, their equipment and expertise can be used in cassava waste collection. Part-time small farmers and large-scale farmers exhibit the greatest potential to be influenced by this new practice due to their capabilities and land availability; however, they face constraints in terms of time and labour. Given the high costs of labor and hiring trucks, the market for cassava waste is anticipated to play a significant role in the decision to adopt the new practice. Overall, for both of these groups the time involved in collecting cassava would be a large factor in their decision.

In addition, cassava waste collection could benefit both farmers and ecosystems. Farmers could earn extra income from selling cassava, which could potentially reduce the indiscriminate burning of cassava waste, which contributes to soil, water and air pollution.

6. Conclusions

This work has shown cassava farmers' current practices vary according to the characteristics of farm type, culture, soil conditions, expertise and technologies, such as fertilization formula, pesticides application, cultivation techniques and so on. According to the adoption of a new practice based on social practice theory, Thai cassava farmers are categorized into three groups (part time small farmer, full time small farmer, large scale farmer). This is based upon the size of cassava farms and their interest in growing cassava. The three groups of farmers have been assessed and have shown that each have different characteristics which affect their current practice in varying ways. These findings are valuable to this study as all types of farmer must be considered in order to adopt the new practice successfully. The cassava waste collection might also benefit the farmers in terms of extra income and use of time effectively. The most important finding of this work is that there are three cassava farming practices which are most affected when collecting cassava waste for use for generation of heat and power; land preparation, fertilization application and waste management. Land preparation is affected as removing cassava waste helps to clear the land, ready for the next crop. However, this may cause more work and energy for the farmers as ploughing may be required to improve soil condition when the cassava waste is taken out of the farm. Fertilization application is also largely affected as when cassava waste is removed, soil nutrients are also removed requiring additional fertilization of the cassava farm. This can cause low yields of cassava. Current knowledge of fertilization application needs to be assessed to enable farmers to learn new techniques of how to fertilise or improve their soil. Their previous fertilizer formulation may need to be updated in order to become suitable for the new practice. Nevertheless, the same skills and expertise in land preparation and fertilization application that farmers already possess could still be applied. Finally, waste management is a significant practice affecting Thai cassava farmers' current cassava waste management. The current practice involves burning or ploughing the waste, whereas the new practice involves collecting and selling the cassava waste. This is an entirely new practice, as neither burning nor ploughing are required, and a new method of collection is needed. The implication of this new practice is that it is time consuming and costly. In addition, extra labourers will be required to assist with the new practice to collect the waste for large cassava farms. The requirement of large amounts of cassava waste for production of heat and power may require well management of cassava waste collection. However, despite changing the practice, the change is not significant to cassava farmers, who can use their existing knowledge and harvesting skills in collecting the waste from cassava farms. To conclude, the production and collection of cassava waste as a new agricultural practice affects cassava farmers and their current farming practices.

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References

Arjharn, W., 2001. Raw material technology assessment of cassava stock utilization of energy production. Suranaree University of Technology. Available at: http://ird.sut.ac.th/ird_engine/view_detail.php?mode=research&id=592.

Arthey. T, Srisompun. O, and Zimmer. Y (2018), Cassava Production and Processing in Thailand – Report to FAO. Available at: http://www.agribenchmark.org/fileadmin/Dateiablage/B-Cash-Crop/Reports/CassavaReportFinal-181030.pdf

Convery, I. et al., 2012. The willingness of farmers to engage with bioenergy and woody biomass production: A regional case study from Cumbria. Energy Policy, 40, pp.293–300.

DEDE (Department of Alternative Energy Development and Efficiency), 2006. Study and Design for Pilot Power Plant Using Cassava Rhizome. Department of Alternative Energy Development and Efficiency in Thailand.

DEDE (Department of alternative Energy Development and Efficiency), 2011. Annual Report: Thailand Alternative Energy Situation 2011.

DEDE (Department of alternative Energy Development and Efficiency), 2009. Biomass potentials in Thailand. Department of alternative energy development and efficiency.

DEDE (Department of alternative Energy Development and Efficiency), 2012. The renewable and alternative energy development plan for 25 percent in 10 years (AEDP 2012-2021).

Demirbas, A, 2004. Combustion characteristics of different biomass fuels. Progress in Energy and Combustion Science, 30(2), pp.219–230.

Edwards-Jones, G. 2007. Modelling farmer decision-making: concepts, progress and challenges. Animal Science, 82(06), p.783.

FAO, 2000. A review of cassava in Asia with country case studies on Thailand and Viet Nam. In the validation forum on the global cassava development strategy. Rome, Italy. Available at: http://www.fao.org/docrep/009/y1177e/y1177e00.htm

FAO, 2014. Food and Agricultural commodities production. FAOSTAT. Available at: http://faostat.fao.org/site/339/default.aspx

FINPRO, 2002. Feasibility study of power generation in combined heat & power mode (CHP) from cassava rhizome & other agriculture biomass residues in Thailand, Finland.

Garforth, C.J., Bailey, P. & Tranter, R.B., 2013. Farmers' attitudes to disease risk management in England: a comparative analysis of sheep and pig farmers. Preventive Veterinary Medicine, 110(3-4), pp.456–66.

Greiner, R., Patterson, L. & Miller, O., 2009. Motivations, risk perceptions and adoption of conservation practices by farmers. Agricultural Systems, 99(2-3), pp.86–104.

Griffin, M.R. & Frongillo, E.A., 2003. Experiences and perspectives of farmers from Upstate New York farmers ' markets. Agriculture and Human Values, Volume 20, Issue 2, pp 189–203

Howler, R., Watanonta, W. & Ngoan, T.N., 2007. Farmer Participation in Research and Extension: The Key to Achieving Adoption of More Sustainable Cassava Production Practices on Sloping Land in Asia and Their Impact on Farmers Income. Monitoring and Evaluation of Soil Conservation and Watershed Development Projects. Eds. Jan de Graaff, John Cameron, Samran Sombatpanit, Christan Pieri, Jim Woodhill. IAC, Wageningen University and Research Centre, NL. Science Publishers, pp.434–476.

Jensen, K., Clark, C.D, Ellis, P, English, B, Menard, J, Walsh, M, Ugarte, D ., 2007. Farmer willingness to grow switchgrass for energy production. Biomass and Bioenergy, 31(11-12), pp.773–781.

Khonwan (2008), Growing Cassava In Thailand, Farming in Thailand Forum, https://www.thaivisa.com/forum/topic/188328-growing-cassava-in-thailand/

Liu, S.-Y. & Lin, C.-Y., 2009. Development and perspective of promising energy plants for bioethanol production in Taiwan. Renewable Energy, 34(8), pp.1902–1907.

Msikita, W. et al., 2000. Disease control in cassava farms. External factsheets, pp.1–15.

Murray-Prior, R., 1998. Modelling farmer behaviour: a personal construct theory interpretation of hierarchical decision models. Agricultural Systems, 57(4), pp.541–556.

OAE, 2017. Thailand agricultural production information. Available at www.oae.go.th

OAE, 2010. Agricutural production in Thailand, Available at: http://www.oae.go.th/

OAE, 2013. Cassava production in Thailand. Office of Agricultural Ecomics. Available at: http://www.oae.go.th/download/prcai/DryCrop/cassava.pdf

Ostwald, M, Jonsson, A, Wibeck, V, Asplund, T., 2013. Mapping energy crop cultivation and identifying motivational factors among Swedish farmers. Biomass and Bioenergy, 50, pp.25–34.

PAN UK, 1996. Paraquat fact sheet, UK. Available at: http://www.pan-uk.org/pestnews/Actives/paraquat.htm

Prakash, A. (2008). Competitive Commercial Agriculture in Sub-Saharan Africa (CCAA) Study.

Available at: http://siteresources.worldbank.org/INTAFRICA/Resources/257994-121545 Z1788567/cassavaprofile.pdf

Paulrud, S. & Laitila, T., 2010. Farmers' attitudes about growing energy crops: A choice experiment approach. Biomass and Bioenergy, 34(12), pp.1770–1779.

S. Sangpetch, S & Sangkasaad, S , Power generation from cassava biomass, PowerCon 2000. 2000 International Conference on Power System Technology. Proceedings (Cat. No.00EX409), Perth, WA, Australia, 2000, pp. 1493-1494 vol.3.

Shove, E., Pantzar, M. & Watson, M., 2012. The dynamics of social practice: everyday life and how it changes, SagePublications Ltd; 1 edition .

Sutabutr, T, Alternative Energy Development Plan: AEDP 2012-2021, International Journal of Renewable Energy, Vol. 7, No. 1, January - June 2012 Available at: http://www.sert.nu.ac.th/IIRE/FP_V7N1(1).pdf

Appendix 1:

Among a larger set of questions about their current practices, farmers were asked the following questions:

- Would you please tell me about your work/role or what you do? (*particular current practices/activities*)
- Are there any barriers to growing cassava? If so, please describe them.
- Have you faced any problems with changing your current practices?
- If so, what happened, and were there any effects on other activities?
- Were there any barriers to implementing these changes?
- How do you receive your information?
- Do you rely on your neighbours or the local community for help or advice?
- If so, what kind of information or help do they provide?
- What do you do with the cassava waste in your fields?
- If you had the opportunity to change your current cassava waste management practices, what would you change?
- Would there be any barriers to implementing this change?

Here it should be noted that not all interviewees were asked all of the questions; rather, the questions were served as a framework to guide the interviews. For each question, it was assumed that if an interviewee did not discuss any issues, he or she either did not believe any were involved or that they were significant. Interview duration ranged between thirty and sixty minutes.