

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. Besides, 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, fertilisation application and waste management— would be impacted by this new strategy. The connections between each of these potentially affected activities have 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.

Keywords: cassava waste, farming practices, Thailand

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 [1] which mandates an increase in domestic alternative energy production to 25% of national energy resources by 2021 [2].

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 [2]. 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. Utilising 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 very well-developed industry and market in Thailand, and it is considered one of Thailand's most important economic plants with over 31 million tons produced in 2016, from less than 1.5 million hectares of plantations [3]. Thailand is the second-largest producer of cassava in the world, behind Nigeria [4]. 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% [5]. 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 [6]. 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.

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 [7].

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Typically, 20% of cassava stem residue is collected post-harvest for use as planting stock, 29% is employed as fertiliser and nearly 10% is lost during harvest [7]. Similarly, the rhizomes of the cassava plant are not used for any practical purpose, as their hard shells contain a high percentage of silica, making them difficult to break and ignite [8]. 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 [6].

Studies of cassava waste utilisation [9, 10] found that cassava waste combustion has massive potential in Thailand to displace fossil fuels for heat and electricity generation and shows promise for further development as an energy source. Sengpetch [9] 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 five times more than rice husks. Cassava rhizomes and stems contain relatively low alkali and chlorine content (0.122%) [10] and low nitrogen, sulphur and ash content (1.27 %, <0.1 % and 4.05% on a dry weight basis, respectively). The nitrogen, sulphur, carbon and ash contents of fossil fuels directly affect greenhouse gas emissions, corrosion levels and ash deposition [8]. Cassava waste, when cofired with coal in cassava-based bioethanol plants, could potentially reduce sulphur dioxide (SO₂) and nitrogen dioxide (NO_x) emissions of these plants. Arjhar [1] 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.

Key elements for the adoption of new farming practices

Many international studies have focused on farmers' adoption of new technologies and practices. Factors deemed to be relevant include: farmers' characteristics and perspectives [11], behaviours [12], motivations [13, 14] and attitudes [15, 11]. Besides, several studies specifically address farmers' adoption of new agricultural biomass collection practices for use as renewable energy resources. Paulrud and Laitila [16] 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 Laitila [16] 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 Laitila [16] showed that the farmers who chose to grow bioethanol fuel crops based their decision on those crops that maximise 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. [13] examined the willingness of US farmers in Tennessee to grow switchgrass 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 ready to build it if it were profitable. In general, they were concerned that technical assistance would be required and that markets were not yet sufficiently developed. Besides, younger farmers with higher levels of educational attainment and off-farm incomes were willing to convert a more significant proportion of farmland. Moreover, farm size and the use of leased farmland correlated negatively with the willingness to convert hectares to switchgrass production. Besides, while erosion issues did not appear to turn their lands for growing switchgrass, desire to provide wildlife habitat did.

These two studies identify several variables that can be expected to affect the adoption of new waste management practices. These include farmer characteristics (e.g. age, farm size, background and expertise), effective utilisation of current agricultural 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. [3] 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 [3] 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 the new method 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 [3] research, suggest the need to move beyond general agricultural demographic and economic factors to consider social, cultural and attitudinal factors. A fundamental 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 farming wastes could be employed for biofuel production, it is essential 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.

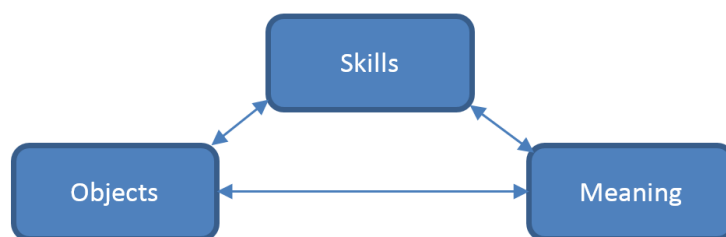
A key objective in this research is to provide a 'snapshot' of the current practices of Thai cassava farmers to anticipate and support the implementation of a new cassava waste collection program for the production of heat and power in bioethanol plants.

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 [17] approach to a consideration of what might occur in the Thai agricultural community if the new cassava waste practice is introduced. Therefore, the study focuses on the relationship between current farming practices and the envisioned new practice; social practice theory (precisely the three elements of material, competence and meaning) is used to model both current practices and the first 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 underlying claim of social practice theory concerning agriculture is that thriving agriculture depends on the relationships between these elements. Objects include agricultural tools, fertilisers, soil health and plant stock. Skills include farmers' skills and expertise of how to use the material features. Meaning refers to the hopes and expectations to which farmers ascribe their success in growing cassava.

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 connections for an original method 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 ties within current practice, making way for new approaches and understanding which could be carried over from the current practice [18]. Shove et al. [18] also noted that innovation in practices could 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 makeup cassava farming.



Skills: using agricultural tools, driving tractor skill, the expertise of current practice, the expertise of soil condition and cassava, time management and waste disposal.

Objects: Agricultural tools, fertilisers, 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 [17]

In this study, social practice theory is employed to study how Thai cassava farmers' current practices may be affected by the adoption of new methods, and to investigate how existing 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 were 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. Besides, 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-kilometre 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 a 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.

Data analysis

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

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 for 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, fertilisation 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.

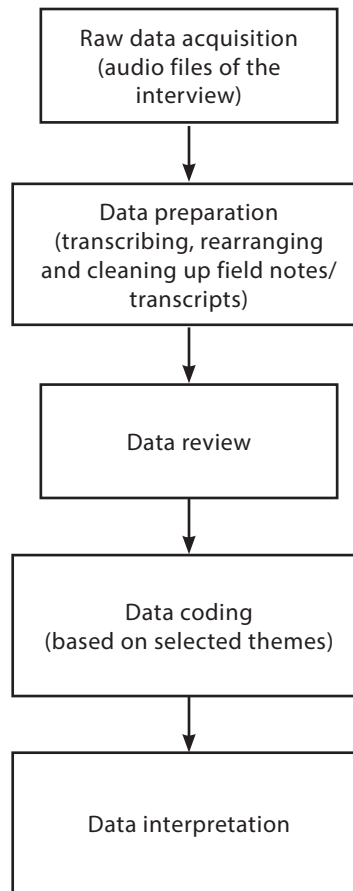


Figure 2 Qualitative data analysis process

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.

Common 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 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 [2]. While cassava is grown as a cash crop by farmers, in most instances it does not provide the sole source of livelihood for the household.

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.

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 rented 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.

Full-time small-scale farmers

Most full-time small farmers are more sophisticated in terms of farming expertise and have developed competencies that help them face contingencies that might occur on their farms. Their primary 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. Besides, 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.

Large-scale farmers

Large-scale farmers are significant investors in the cassava business. Their cassava plantations are usually larger than 50 rais (1 rai = 0.16 hectare). These farmers typically 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 full-time, experienced labourers.

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 critical practices in cassava production are well known and include land preparation, planting, fertilisation application, weed

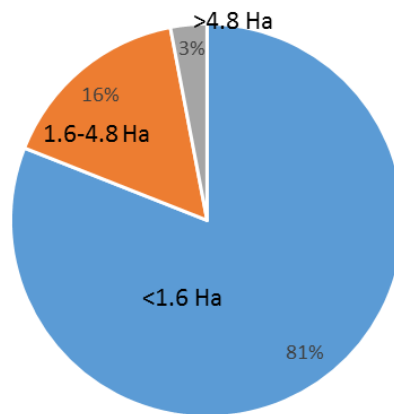


Figure 3 Farm size area in Thailand [2]

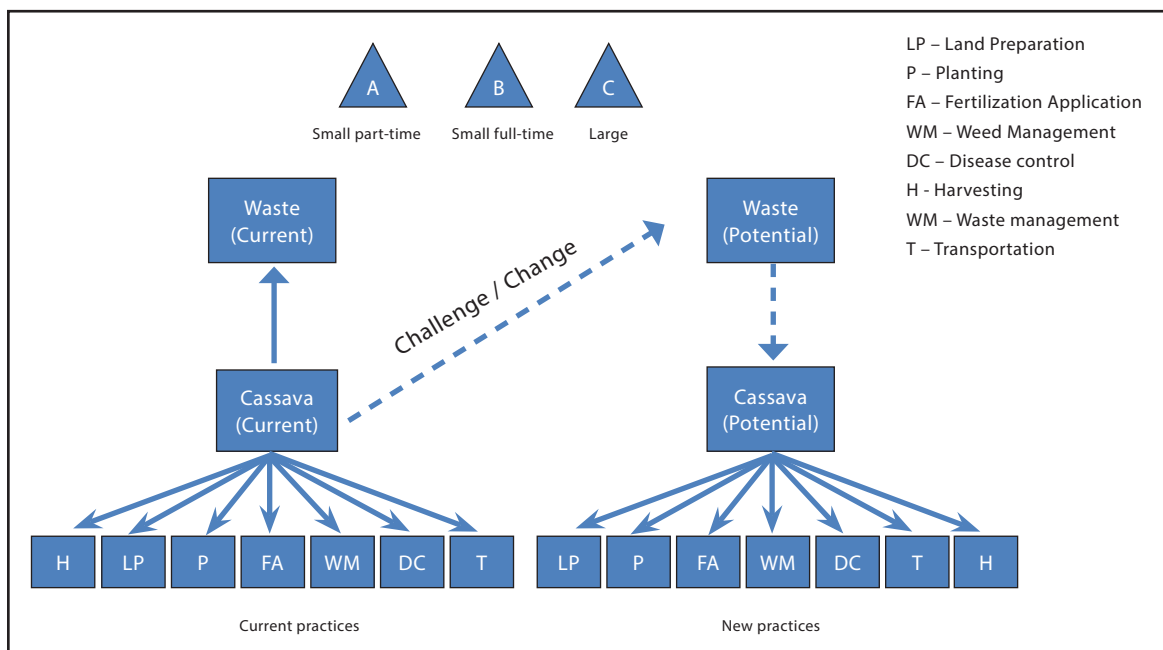


Figure 4 Framework for existing and new practices

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 method may weaken or break the links between the meaning, materials and skills of the current practice.

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 new practice (cassava waste collection) and the considerations that this practice may require. 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 the previous section), three of which (land preparation, fertilisation 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 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 modelled using social practice theory. According to social practice theory, the introduction of a new method 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 relationships between the elements of the current practice and the new one (Figure 4). If new links are not established, modern 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 the production of heat and power in bioethanol plants.

In the following discussion, each of the three potentially affected activities will be analysed 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 harmful aspects and obstacles to the implementation of this new practice will be identified. The likely impediments to 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 method 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.

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 before planting the next crop. In terms of expertise and skill, an understanding of soil conditions, the knowledge in operating a tractor and plough and the ability to plough and farrow are all necessary for land preparation.

The potential relationship between land preparation and cassava waste collection practices is illustrated in Figure 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 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.

Another possible effect concerns efficiency. In preparing the land, before ploughing cassava farmers must remove any residual cassava waste by harrowing. But by eliminating the cassava waste for the production of heat and power, farmers 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.

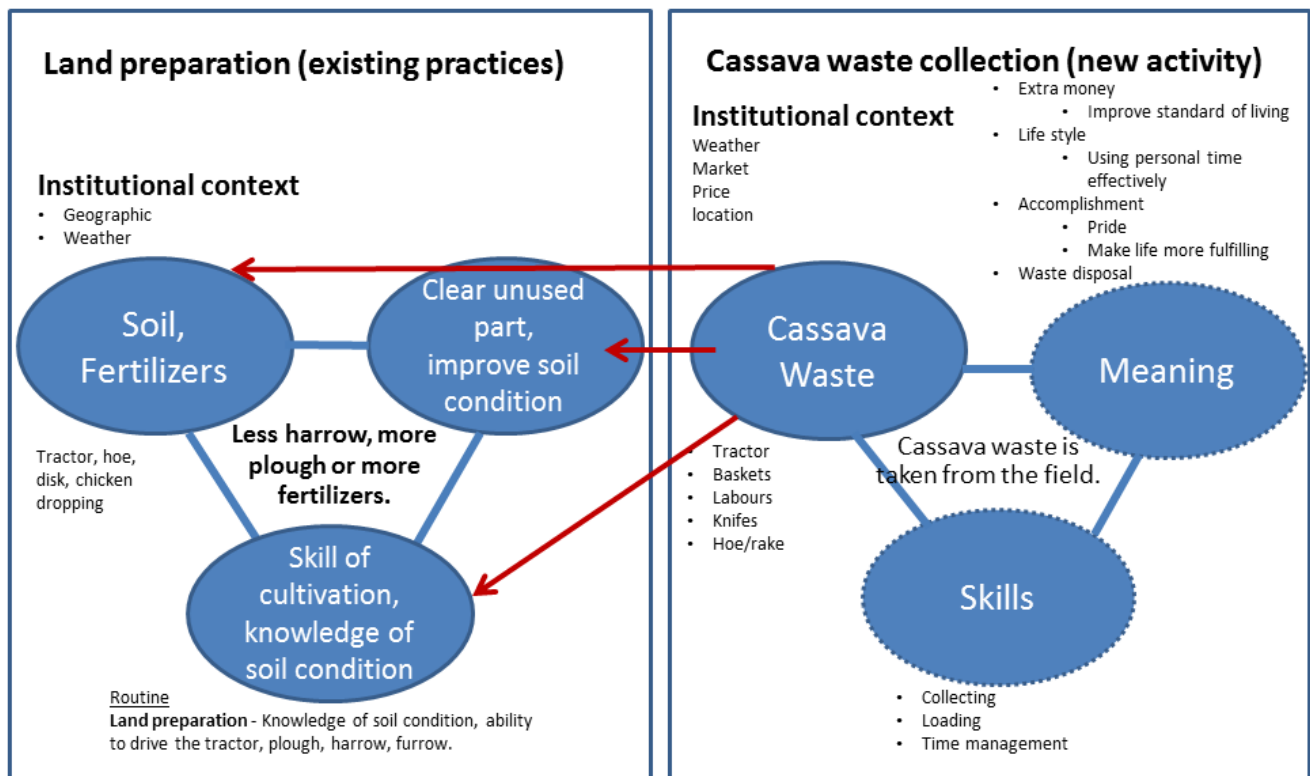


Figure 5 Connections between land preparation and cassava waste collection practices

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 fertiliser 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. Besides, 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 more significant 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 to avoid excess ploughing, and other related work after the new practice is adopted. Besides, 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

Fertilisation application

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

Figure 6 illustrates that new fertiliser formulas or types, new NPK ratings/values and additional fertiliser applications might be required to maintain soil nutrition given cassava waste removal. This could require more considerable investments for farmers to maintain soil nutrition, but might also lead to 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 fertiliser application. However, familiarity with fertiliser application methods and an understanding of cassava cultivars might be necessary for farmers in addressing problems arising from cassava waste removal. Notwithstanding, there is a shortage 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 affect cassava yields. Moreover, farmers hold conflicting views as to the utility of cassava waste as a fertiliser, and little evidence exists to support this point, questioning the validity of this argument.

can cause low yields of cassava, especially in large scale farms, which incurs potentially high costs for extra fertiliser and poor crops. This could be a massive loss for these farmers if additional fertilisers 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 fertilisation application. Their fertilisation application practices are dependent upon finances, i.e. if income increases, additional fertiliser may be purchased. Farmers in this

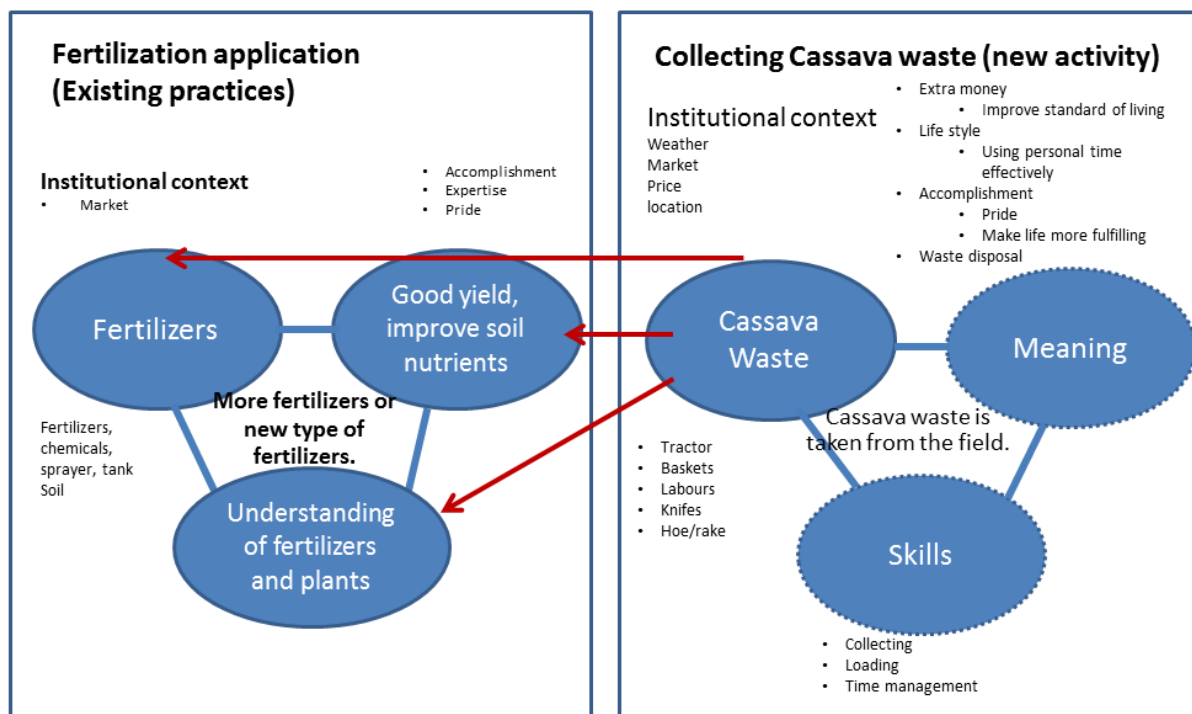


Figure 6 Connections between fertilisation application and cassava waste collection practice

In terms of the anticipated effect of this new practice on fertilisation application practices across types of farmers, the analysis suggests that implementation could affect the fertilisation practices of all farmers. However, it could have a particularly significant effect on large-scale farmers. Due to their vast landholdings, farm maintenance is often challenging, which has consequences for soil fertility. Large scale farmers do not generally apply large quantities of fertiliser, but rather apply fertiliser only when necessary or to specific productive areas that are near resources (i.e. pond, canal) or exhibit right soil conditions. Thus, farmers in this group typically do not apply fertilisers to their entire farms because this is cost-prohibitive. In areas where fertiliser is not used, the waste collection could lead to a lower cassava yield. Not changing or adapting fertiliser formulation

group usually attempt to find the right balance of fertilisation method and fertiliser type to maximise cassava yield, as they own relatively smaller farms. Thus, full-time small farmers generally apply greater amounts of fertiliser than other farmers. This practice typically results in more fertile soil, which can produce higher yields, which in turn allows for more significant 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 fertilisation application practices.

Finally, the analysis does not suggest any significant impacts on fertilisation application practices for part-time small farmers. These farmers typically do not consider fertilisation application

important, as cassava waste is not regarded as a priority. Generally speaking, the data suggest that farmers in this group usually do not adequately maintain their fields, and practice only the most basic fertilisation methods due to constraints of time and labour. Overall, fertilisation application methods will impact the new cassava waste collection practice, but the different approaches are taken to fertilisation 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 fertilisation application practised by each group, a farmer's financial situation is another factor in how fertilisation application. Applying incorrect amounts or types of fertilisers could lead to increased costs, which is detrimental to lower-income farmers. Therefore, expertise in fertilisation 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 fertiliser formulation may need to be updated to become suitable for the new practice.

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 methods and the effect of the new process on waste management are shown in Figure 7.

Figure 7 indicates that cassava waste collection could affect time and labour expenditures in cassava waste management practices. Concerning 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 the 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 the collection.

According to the three critical elements of social practice theory, the meaning element of current waste management practice would be affected when the collection of cassava waste is introduced. The

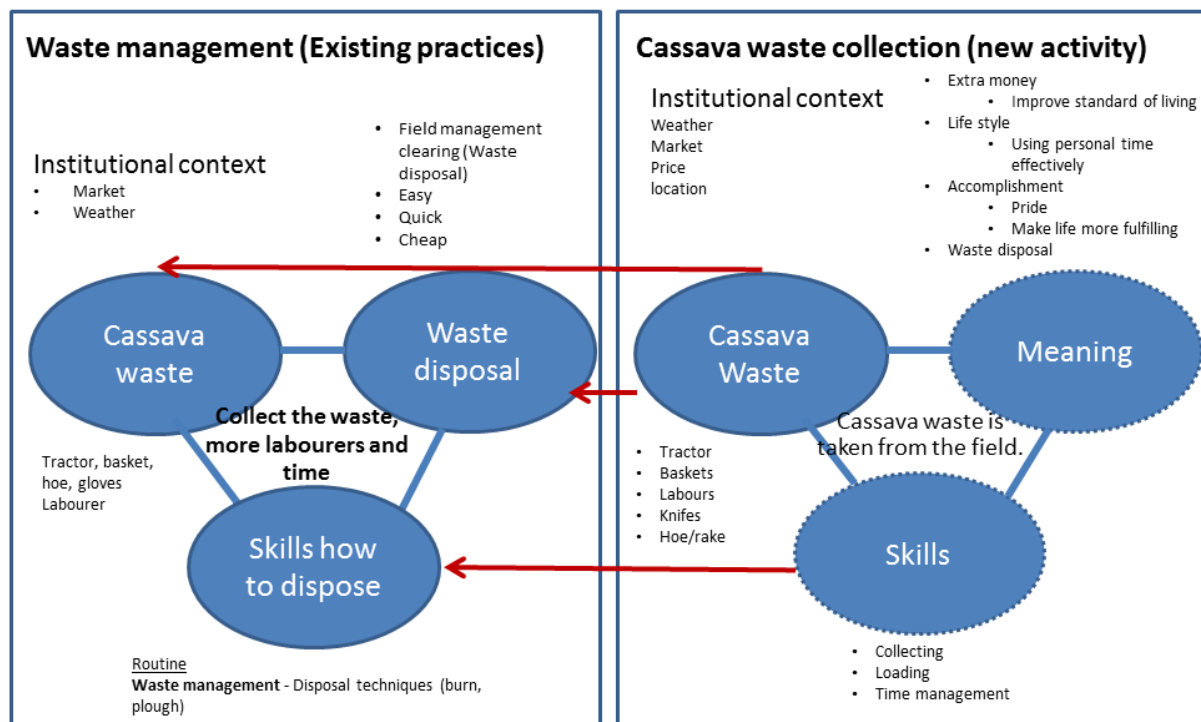


Figure 7 Connections between waste management and cassava waste collection practices

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

meanings of cassava waste collection include: clearing out unused parts, time-consuming and profit. As the new practice could result in the 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 trash, 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 significant 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 the debris 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 method, and extra income earned from selling cassava waste could potentially improve their quality of life. The most critical priority for farmers in this group is to maximise farm returns; thus, substantial 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 revenue or allocate time effectively.

Concerning 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 trash 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 highest potential to take 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 highest 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 labour 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 substantial factor in their decision.

Besides, 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 the soil, water and air pollution.

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 fertilisation 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 has different characteristics which affect their current practice in varying ways. These findings are valuable to this study, as all types of the farmer must be considered 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 generations to use of heat and power; land preparation, fertilisation 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. Fertilisation

application is also primarily affected as when cassava waste is removed; soil nutrients are also removed requiring additional fertilisation of the cassava farm. This can cause low yields of cassava. Current knowledge of fertilisation application needs to be assessed to enable farmers to learn new techniques of how to fertilise or improve their soil. Their previous fertiliser formulation may need to be updated to become suitable for the new practice. Nevertheless, the same skills and expertise in land preparation and fertilisation 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 present method involves burning or ploughing the waste, whereas the new practice consists of collecting and selling cassava waste. This is an entirely new practice, as neither burning nor ploughing is required, and an original method of collection is needed. The implication of this new practice is that it is time-consuming and costly. Besides, extra labourers will be required to assist with the original method to collect the waste for large cassava farms. The requirement of large amounts of cassava waste for the 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.

Acknowledgements

The authors would like to acknowledge the support of the Energy Policy and Planning Office (EPPO), Ministry of Energy, and the Department of Alternative Energy Development and Efficiency (DEDE), Royal Thai Government. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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