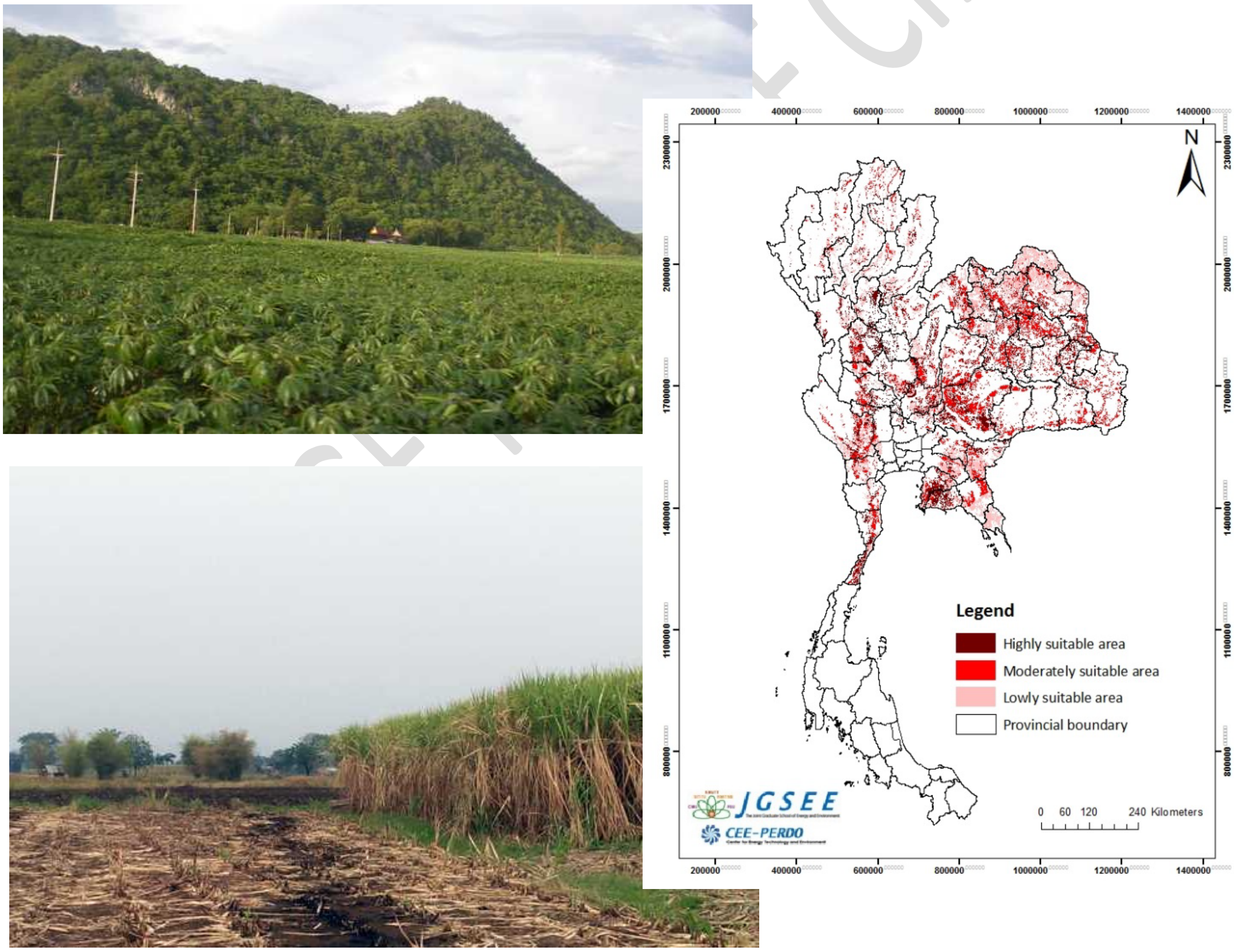
COLLABORATION DE RECHERCHE TOTAL – CIRAD DS 2389

Analyse et évaluation du potentiel de développement des cultures énergétiques

Etude pays

THAILANDE



S. Bonnet, S. Garivait, P. Cheewapongphan et L. Gazull

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Avertissement

Le présent rapport a été réalisé dans le cadre de la convention de collaboration CIRAD/TOTAL DS 2676.

Cette collaboration avait pour objectifs :

- De développer une méthode « bottom-up » permettant d'évaluer les terres disponibles pour la production durable de cultures énergétiques à l'échelle d'un pays ;
- D'éprouver cette méthodologie dans neuf pays tropicaux;
- De produire trois atlas mondiaux des plantes à fort potentiel bioénergétiques ;
- De développer une base de données mondiale d'indicateurs nationaux des potentiels de production de biocarburants

Le présent rapport synthétise une des neuf études réalisées à l'échelle nationale.

Les résultats de cette étude sont soumis aux règles de confidentialité définies dans la convention CIRAD/TOTAL DS 2676 : toute publication ou communication d'informations relatives à cette étude, par l'une ou l'autre des Parties (CIRAD ou TOTAL), devra recevoir l'accord écrit de l'autre Partie.

Executive Summary (Français)

1. le contexte thailandais

La consommation d'énergie en Thaïlande a constamment augmenté au cours des dernières années. La Thailande dépend fortement des importations de pétrole fossile pour satisfaire sa demande énergétique avec environ 60 pour cent de sa demande totale d'énergie venant de l'extérieur. L'importation de pétrole fossile se traduit par un coût financier lourd et pose des questions de sécurité énergétique pour le pays. À l'heure actuelle, les secteurs de l'industrie et des transports représentent à part égale plus de 70% de la demande (DEDE, 2012). Fort de son potentiel de production de biomasse agricole, le gouvernement thaïlandais a fait beaucoup d'efforts au cours des 15 dernières années dans la promotion des énergies renouvelables (ER). L’objectif fixé pour 2021 est d’augmenter la production d’ER à hauteur de 25% de demande totale en énergie finale. En ce qui concerne le secteur des transports, les biocarburants ont été fortement encouragées, notamment l'éthanol pour lequel un objectif de production de 9 millions de litre/jour à l’horizon 2021 a été fixé.

Les deux ressources principales pour la production d'éthanol sont le manioc (cassava) et la canne à sucre (sugar cane).

En Thaïlande, environ 47 % de la couverture totale du pays sont dédiés à la production agricole. Le climat et les conditions de sol sont très favorables à la production agricole en général. Environ 11 % de la superficie agricole est occupée par les plantations de manioc et de canne à sucre. Ces plantations se trouvent partout en Thaïlande, sauf dans le sud où les précipitations sont trop élevées. En 2012, les zones de plantation de manioc et de canne à sucre couvraient respectivement environ 1,4 million d'ha et 1,3 million ha. Les productions de manioc (rendement moyen de 21,9 tonnes/ha) et de canne à sucre (rendement moyen de 75,7 tonnes/ha) étaient respectivement de 29,4 et de 98,4 millions de tonnes. Il est important de noter que la Thaïlande est le deuxième pays exportateur mondial de manioc et de sucre (et de produits sucrés).

En raison du bon potentiel de la Thaïlande pour la production agricole, le gouvernement souhaiterait élargir les plantations de manioc et de canne à sucre afin d'augmenter la production de biocarburants.

Cette étude se concentre sur l’évaluation du potentiel de production durable de manioc et de canne à sucre conformément aux directions données par le gouvernement thailandais et aux conditions actuelles de production de ces deux cultures. Ces directions sont clairement de limiter les changements aux terres où les rendements actuels des cultures en place sont faibles (zones peu rentables) et de limiter le remplacement des cultures vivrières.

2. Cadre méthodologique

Pour effectuer cette évaluation, une méthodologie a été développée consistant à identifier les terres disponibles qui pourraient être utilisées afin de maximiser les zones de production du manioc et de canne à sucre. Il s’avère très clairement qu'il y a en Thailande, une saturation des terres utilisées pour la production agricole, et donc très peu de possibilités d'expansion du manioc et de canne à sucre sur des terres incultes. Les seules possibilités d’expansions résident dans le remplacement (commutation) d’une culture non énergétique actuellement en place par une des deux cultures énergétiques visées. La méthode d’évaluation repose donc sur la recherche des terres dont les cultures actuelles sont susceptibles d’être remplacées par du manioc ou de la canne à sucre.

Les critères retenus pour déterminer les conditions de ce remplacement sont fondés sur des considérations de qualité des terres (les conditions du sol et la disponibilité de l'eau répondant aux exigences de croissance du manioc et de canne à sucre), sur les directions données par le gouvernement et sur la prise en compte de facteurs environnementaux et sociaux.

Conformément à ces règles, le remplacement des cultures maraichères, fruitières et du riz irrigué, ne peut être envisagé. Il apparait alors que seules les trajectoires suivantes sont économiquement et socialement acceptables par le gouvernement thailandais.

Manioc -> Canne à sucre

Canne à sucre -> manioc

Riz pluvial des hautes terres (Highland rice) -> canne à sucre ou manioc

Compte tenu de la production largement excédentaire en riz irrigué (dont la Thailande est un gros exportateur), le remplacement du riz pluvial par une culture destinée à l'énergie, est pour les autorités nationales est une solution envisageable car ne remettant pas en cause la sécurité alimentaire du pays.

Les deux scenarios étudiés sont donc les suivants

Scénario 1 : Expansion de la production de canne à sucre par les agriculteurs en place, sur des zones actuellement cultivées en manioc ou en riz pluvial selon la logique suivante : 1/ la production de canne y est théoriquement satisfaisante ; 2/ la culture de manioc n'y est pas optimale; 3) la culture du riz pluvial n'y est pas optimale.

Scénario 2 : Expansion de la production de manioc par les agriculteurs en place, sur des zones actuellement cultivées en canne à sucre ou en riz pluvial selon la logique suivante : 1/ la production de manioc y est théoriquement satisfaisante ; 2/ la culture de canne à sucre n'y est pas optimale; 3) la culture du riz pluvial n'y est pas optimale.

Le détail de l'évaluation est donnée pour chaque culture ci-après.

L'évaluation des potentiels se fait selon un processus hiérarchique allant du potentiel théorique au potentiel de valorisation :

(1) évaluation du potentiel théorique. Il correspond à la zone qui répond aux exigences bioclimatiques pour la culture du manioc ou de la canne à sucre. Cette information a été traitée selon les critères de qualité des terres définis par le ministère de développement des terres de Thaïlande (LDD) pour le manioc et la canne à sucre.

(2) évaluation du potentiel disponible. Il correspond aux surfaces qui (1) sont actuellement utilisées pour la culture du manioc (ou de la canne à sucre) et (2) les zones de terrain qui pourraient être remplacés par du manioc (ou de la canne à sucre) – cf critères définis ci-dessus) et (3) qui respectent certaines exigences environnementales (respect des cours d'eau et des zones de conservation).

(3) évaluation du potentiel technique. Il correspond aux surfaces permettant de répondre aux exigences technico-économiques de la filière et en particulier des usines de transformation (usines de séchage du manioc et sucreries de canne). La récolte du manioc étant majoritairement manuelle, aucune contrainte technique n'a été retenue au niveau de la surface de production. En revanche, un critère de distance maximale aux usines existantes a été appliqué.

(4) évaluation du potentiel de valorisation. Il correspond à la partie du potentiel technique que les producteurs seraient réellement à même de valoriser compte tenu des freins sociaux-culturels liés au changement de culture.

3. Le potentiel théorique du Manioc et de la canne à sucre

Le ministère du développement des terres (LDD) a fourni l'ensemble des informations nécessaires à l'identification des terres favorables à l'implantation du manioc et de la canne à sucre.

Les critères utilisés sont résumés dans le tableau 1 :

Table 1 Land quality suitability classes for cassava and sugarcane

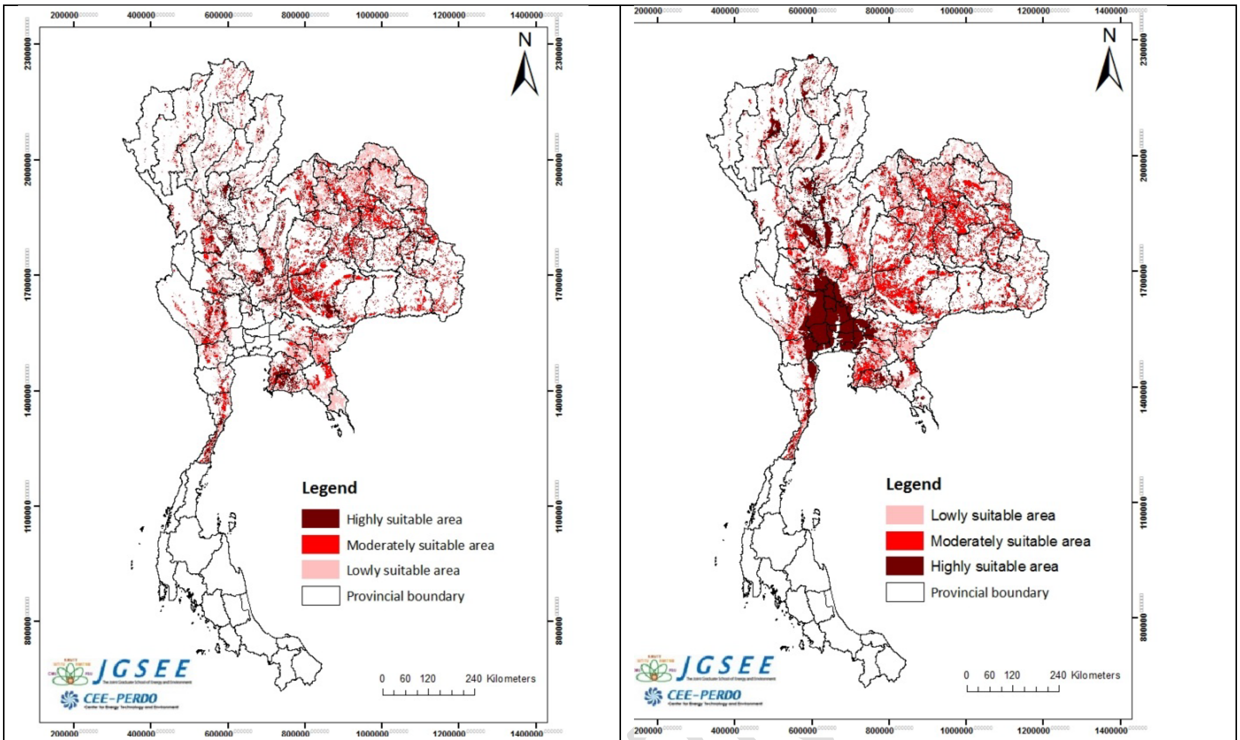
Land quality	Diagnostic factor	Crop requirement in each level			
		Highly suitable (S1)	Moderately suitable (S2)	Lowly suitable (S3)	Unsuitable
Water availability	Annual rainfall (mm/yr)	1,100-1,500 (cassava)	900—1,100 1,500-2,500 (cassava)	500-900 2,500-4,000 (cassava)	<500 >4,000 (cassava)
		1,600-2,500 (sugarcane)	1200-1600 (sugarcane)	900-1200 (sugarcane)	>900 (sugarcane)
Physical property of soil	Soil depth (cm)	>100	50-100	25-50	<25
	Soil texture	C, L, SCL, SiL, Si,CL,L,SL,SiCL (cassava)	LS (cassava)	SiC (cassava)	C,G,SC,AC,S
		C, L, SCL, SiL, Si, CL, L (sugarcane)	SiCL, SL (sugarcane)	SiC, LS (sugarcane)	
Chemical property of soil*	pH	6.1-7.3	7.4-7.8 5.1-6.0	7.9-8.4 4.0-4.5	>8.4 <4.0
	N (%)	>0.2	0.1-0.2	<0.1	-
	P (ppm)	>25	6-25	<6	-
	K (ppm)	>60	30-60	<30	-

Remark: SL = Sandy loam, C = Clay (%clay<60), LS = Loamy sand, SC = Sandy clay, C = Clay (%clay>60), S = Sand, G = Gravel soil, SC = Slope complex, AC = Alluvial complex; Source: [10]

Note: *same requirements for cassava and sugarcane

A partir de ces informations et des bases de données géographiques disponibles en Thailande, les zones favorables ont été cartographiées et classées en 3 catégories : S1 (très favorable), S2 (modérément favorable) and S3 (faiblement favorable).

Les cartes résultantes sont données Figures 1(a) et (b).



(a) Manioc (b) canne à sucre

Figure 1 : Le potentiel théorique du manioc et de la canne à sucre

Pour le manioc, l'ensemble des surfaces favorables représente 11,6 millions d'ha, soit environ 23 % de la surface totale de la Thaïlande (cf tableau 1). Seuls 2,5 millions d'ha sont très favorables et 4,3 millions d'ha modérément favorables. Si l'on compare la situation actuelle des plantations de manioc avec la carte de zonage (Fig 1a), on observe qu'environ 70 % du manioc est produit sur des terres favorables alors que 30 % est cultivé sur des terres théoriquement impropres.

Pour la canne à sucre, l'ensemble des surfaces favorables représente 15.0 millions ha, soit environ 30 % de la surface totale de la Thaïlande (cf tableau 1). 4.4 millions ha sont très favorables et 6.6 millions ha modérément favorables. Si l'on compare la situation actuelle des plantations de canne avec la carte de zonage à l'adresse ci-dessus, on observe qu'environ 78 % de la canne à sucre est produit sur des terres favorables alors que 22 % est cultivé sur des terres théoriquement impropres.

4. Evaluation des scénarios de production de Manioc et de Canne à sucre

4.1 Le Scénario « Manioc »

- *Le potential théorique (theoretical potential)*

Il correspond aux zones très favorables (S1) et modérément favorable (S2) à la culture du manioc, selon la terminologie du LDD.

- *Le potentiel disponible (available potential)*

Il correspond :

1) Aux surfaces actuellement cultivées en manioc.
2) Aux surfaces additionnelles actuellement cultivées en canne à sucre ou en riz pluvial et ayant un fort potentiel de production de manioc (surfaces en S1 ou S2). Ces surfaces pourraient être converties en manioc et être considérées disponibles si :
   - Elles sont actuellement cultivées en canne à sucre mais sur des terres faiblement favorable (S3) ou impropres (N) à la canne.
   - Elles sont actuellement cultivées en riz pluvial (highland rice).

De ces surfaces pouvant être converties sont ensuite soustraites les contraintes environnementales suivantes: zones tampon de 1 km autour des forêts, corridors rivulaires de 10m ou 50m autour des cours d'eau (selon l'importance du cours d'eau).

- *Le potentiel technique (Technical potential)*

Le seul critère technique retenu est la distance aux usines actuelles de séchage du manioc : 334 actuellement sont opérationnelles en Thailande. Une distance maximum de 50 km a été retenue à dires d'experts (interviews auprès des producteurs et transformateurs).

- Le potential de valorisation (Realistic potential)

La capacité des agriculteurs à substituer le manioc à la canne ou au riz pluvial a été évaluée par des entretiens auprès des producteurs de canne et de manioc.

4.2 Le Scénario «Canne à sucre »

- *Le potentiel théorique (theoretical potential)*

Il correspond aux zones très favorables (S1) et modérément favorable (S2) à la culture de la canne, selon la terminologie du LDD.

- *Le potentiel disponible (available potential)*

Il correspond :

1) Aux surfaces actuellement cultivées en canne à sucre.
2) Aux surfaces additionnelles actuellement cultivées en manioc ou en riz pluvial et ayant un fort potentiel de production de canne (surfaces en S1 ou S2). Ces surfaces pourraient être converties en canne et être considérées disponibles si :
   - Elles sont actuellement cultivées en manioc mais sur des terres faiblement favorables (S3) ou impropres (N) au manioc.
   - Elles sont actuellement cultivées en riz pluvial (highland rice).

De ces surfaces pouvant être converties sont ensuite soustraites les contraintes environnementales suivantes: zones tampon de 1 km autour des forêts, corridors rivulaires de 10m ou 50m autour des cours d'eau (selon l'importance du cours d'eau).

- *Le potential technique (Technical potential)*

Le seul critère technique retenu est la distance aux usines actuelles de production de sucre : 51 actuellement sont opérationnelles en Thailande. Une distance maximum de 50 km selon une route bitumée a été retenue à dires d'experts (interviews auprès des producteurs et transformateurs)

- Le potential de valorization (Realistic potential)

La capacité des agriculteurs à substituer la canne au manioc ou au riz pluvial a été évaluée par des entretiens auprès des producteurs de canne.

5. Résultats

Les résultats sont consignés dans les tableaux 2 et 3 suivants

Table 2 Les potentiels du manioc

	Area (million ha)
Theoretical potential area for cassava	6.800
- Highly and moderately suitable areas (LDD)	6.800
Available potential area for cassava	1.959
- Existing cassava crop	1.916
- Switching from sugarcane to cassava (scenario-based)	0.013
- Switching from highland rice to cassava (scenario-based)	0.192
- Environmental constraints (area switches from sugarcane to cassava)	-0.010
- Environmental constraints (area switches from highland rice to cassava area)	-0.152
Technical potential area for cassava	1.948
- Existing cassava crop	1.916
- Switching from sugarcane to cassava area	0.002
- Switching from highland rice to cassava area	0.030
Realistic potential area for cassava	1.934
- Existing sugarcane crop (100%)	1.916
- Switching from sugarcane (100%) and highland rice (53%)	0.018

Pour le Manioc, les résultats montrent que les possibilités d'expansion sont faibles : seuls 3000 ha de canne et 40 000 ha de riz pluvial seraient susceptibles d'être transformés en manioc. En considérant les critères techniques de distance aux usines et les freins sociaux-culturels au changement, le potentiel de valorisation se imite à 18 000 ha, soit un potentiel d'augmentation de 0.9% par rapport aux surfaces actuellement plantées en manioc. Le potentiel de conversion de la canne vers le manioc est minime, car les agriculteurs canniers sont très liés aux usines de sucre et ont peu de raison de changer.

Table 3 Les potentiels de la canne à sucre

	Area (million ha)
Theoretical potential area for sugarcane	10.800
- Highly and moderately suitable areas (LDD)	10.800
Available potential area for sugarcane	3.354
- Existing sugarcane crop	1.850
- Switching from cassava to sugarcane (scenario-based)	0.040
- Switching from highland rice to sugarcane (scenario-based)	3.219
- Environmental constraints (area switches from cassava to sugarcane) - Environmental constraints (area switches from highland rice to sugarcane area)	-1.73
Technical potential area for sugarcane	2.553
- Existing sugarcane crop	1.850
- Switching from cassava to sugarcane area	0.015
- Switching from highland rice to sugarcane area	0.688
Realistic potential area for sugarcane	2.126
- Existing sugarcane crop (100%)	1.850
- Switching from cassava (100%) and switching from highland rice (38%)	0.276

Pour la canne à sucre, les résultats montrent que les possibilités d'expansion sont un peu plus fortes que pour le manioc : 40000 ha de manioc et 1.5Mha de riz pluvial seraient susceptibles d'être transformés en canne à sucre. En considérant les critères techniques de distance aux usines et les freins sociaux-culturels au changement, le potentiel de valorisation se imite à 276 000 ha, soit un potentiel d'augmentation de 15% par rapport aux surfaces actuellement plantées en canne.

Executive Summary (English)

1. Background information

Energy consumption in Thailand has been continuously increasing over the years. Thailand depends heavily on importation of fossil oil to satisfy its energy demand with about 60 percent of its total energy demand coming from outside. The importation of fossil oil results in heavy financial cost and poses issues of energy security for the country. At present, more than 70% of the total energy consumed in Thailand is contributed in almost equal share by the industry and transport sectors (DEDE, 2012a). As Thailand is an agricultural country rich in biomass resources, the Thai government has made many efforts over the past 15 years in promoting renewable energy (RE). A target has been set for 2021 where RE should contribute 25% of the total final energy consumption. With regard to the transport sector, biofuels have been strongly promoted, notably, ethanol for which a 9 million litre per day consumption target has also been set for 2021. The two main feedstocks for ethanol production are sugarcane and cassava since Thailand has a geography and topography that supports the production of both crops.

In Thailand, about 47% of the total land coverage is dedicated to agricultural production. This is because the climate and soil conditions of Thailand are quite suitable for agricultural production in general. About 11% of the agricultural area is occupied by cassava and sugarcane plantations. These plantations can be found all around Thailand except in the south where precipitations are too high. In 2012, the cassava and sugarcane plantation areas covered about 1.4 million ha and 1.3 million ha respectively. The production of cassava (average yield is 21.9 tonnes per ha) and sugarcane (average yield is 75.7 tonnes per ha) was 29.4 million tons and 98.4 million tonnes respectively. It is important to note that Thailand is a country among the major producers of cassava and sugarcane and which is notably the second largest exporter of cassava and sugar (an
d sugar products) in the world.

Because of the good potential of Thailand for agricultural production, cassava and sugarcane plantations could potentially be expanded to enhance biofuel production. In this study, areas of Thailand that could be suitable for cassava and sugarcane plantations were investigated and scenarios of production that are appropriate to produce bioethanol assessed.

2. Methodological framework

To perform this assessment, a methodology was followed consisting in identifying potential areas of land that could be used to maximize the production areas of cassava and sugarcane. The scenarios for maximizing the production of cassava and sugarcane were developed based on the assessment of the maximum "suitable switchable" area that could be used for planting these 2 crops. The "suitable switchable" area is defined as the area that could be switched from a current crop use to either cassava or sugarcane based on land suitability considerations (soil conditions and water availability meeting the growth requirements of cassava and sugarcane). As there is a saturation of the land used for agricultural production in Thailand, there are very few possibilities for expansion of cassava and sugarcane on uncultivated land. Only highland rice was identified as a potential switchable area. This is because the Thai government has a policy in place consisting in promoting the plantation of sugarcane in highland rice areas. Since, the soil conditions requirements for cassava and sugarcane production are fairly similar, there may be situations where highland rice is located on land which soil conditions are suitable for either crop. In that case, sugarcane would be considered as the first priority for the switch (based on the policy of the Thai government).

The assessment of the maximum potential area for cassava and sugarcane production was based on the determination of a number of potential areas, as detailed below:

(1) Assessment of the theoretical potential area. This corresponds to the area that meets the requirements for cassava or sugarcane cultivation. This information was processed based on the land quality criteria defined by the Land Development Department in Thailand for cassava and sugarcane.

(2) Assessment of the available potential area based on the previous step. It corresponds to (1) the area that is currently used for cassava (or sugarcane) cultivation and (2) the areas of land that could be switched to cassava (or sugarcane) and which also account for certain environmental constrains (buffer zones).

(3) Assessment of the technical potential area. Following the determination of the available potential area, infrastructure considerations (road network and location of cassava factories and sugar mills) were included as part of the assessment to narrow down the land area that can technically be considered for cassava and sugarcane production. This step identifies the maximum potential area that could be used for cassava and sugarcane production.

(4) Assessment of the realistic potential area. *It corresponds to* the technical potential area that stakeholders could operate in accordance with their capacity to switch from a crop to another.

3. Cassava and sugarcane zoning areas

The land Development Department (LDD) provides information identifying the soil conditions and water requirements for cassava and sugarcane production. This information is shown in Table 1.

Table 1 Land quality suitability classes for cassava and sugarcane

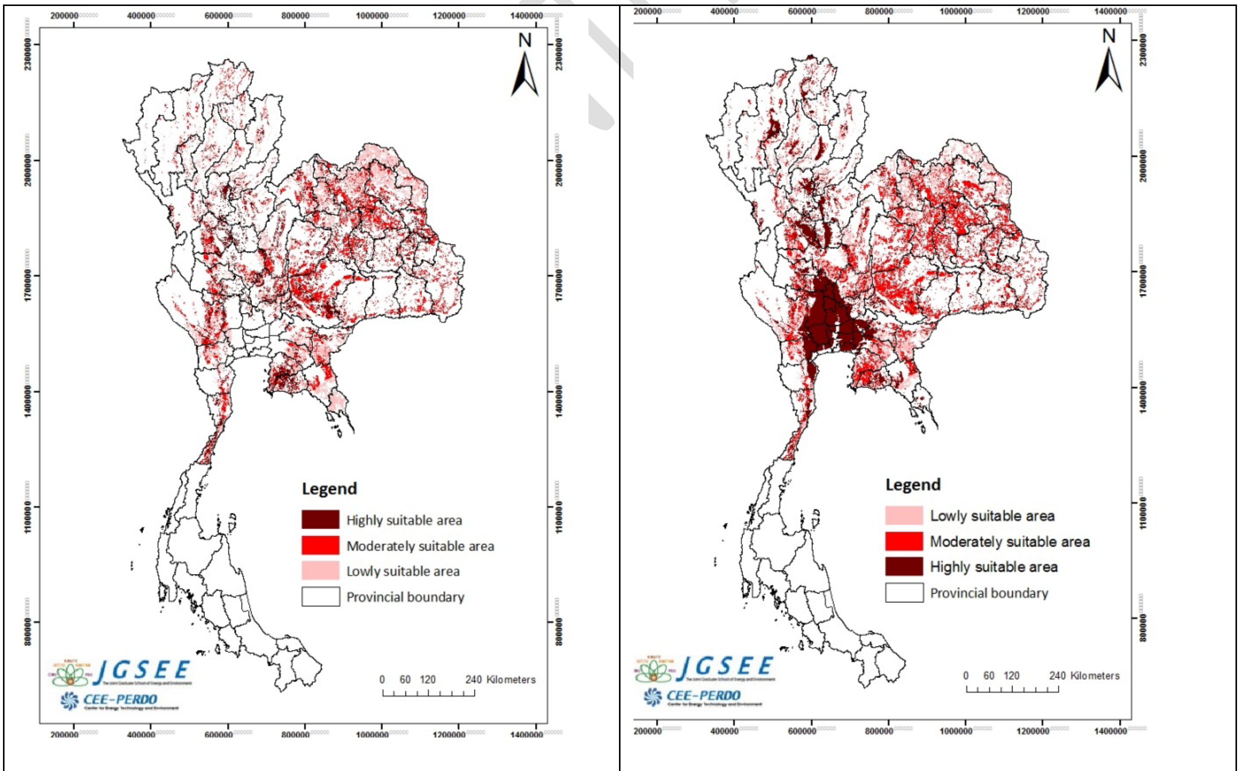
Land quality	Diagnostic factor	Crop requirement in each level			
		Highly suitable (S1)	Moderately suitable (S2)	Lowly suitable (S3)	Unsuitable
Water availability	Annual rainfall (mm/yr)	1,100-1,500 (cassava)	900—1,100 1,500-2,500 (cassava)	500-900 2,500-4,000 (cassava)	<500 >4,000 (cassava)
		1,600-2,500 (sugarcane)	1200-1600 (sugarcane)	900-1200 (sugarcane)	>900 (sugarcane)
Physical property of soil	Soil depth (cm)	>100	50-100	25-50	<25
	Soil texture	C, L, SCL, SiL, Si,CL,L,SL,SiCL (cassava)	LS (cassava)	SiC (cassava)	C,G,SC,AC,S

		C, L, SCL, SiL, Si, CL, L (sugarcane)	SiCL, SL (sugarcane)	SiC, LS (sugarcane)	
Chemical property of soil*	pH	6.1-7.3	7.4-7.8 5.1-6.0	7.9-8.4 4.0-4.5	>8.4 <4.0
	N (%)	>0.2	0.1-0.2	<0.1	-
	P (ppm)	>25	6-25	<6	-
	K (ppm)	>60	30-60	<30	-

Remark: SL = Sandy loam, C = Clay (%clay<60), LS = Loamy sand, SC = Sandy clay, C = Clay (%clay>60), S = Sand, G = Gravel soil, SC = Slope complex, AC = Alluvial complex; Source: [10]

Note: *same requirements for cassava and sugarcane

Based on the land quality information provided by LDD, cassava and sugarcane zoning area maps were produced identifying the total area that could potentially be considered for their respective production (ignoring what that land may currently be used for). A classification based on land suitability levels was also identified, i.e. S1 (high suitability), S2 (moderate suitability) and S3 (Low suitability). The cassava and sugarcane maps are shown in Figures 1(a) and (b).



(a) Cassava plantation

(b) Sugarcane plantation

Figure 1 cassava and sugarcane zoning area maps

For cassava, it was found that the total land area that could potentially be considered for its production amounts to 11.65 million ha; this represents about 22.7% of Thailand's total land surface. Based on the land suitability levels reported in table 1, this breaks into 2.5 million ha of highly suitable land, 4.3 million ha of moderately suitable land and 4.7 million ha of lowly suitable land. Therefore, low to medium land quality conditions appear to dominate the overall land quality conditions potential for cassava production. When comparing the existing cassava plantation situation with the above zoning area map, it was observed that about 70% of the current (existing) area of cassava (1.3 Mha) is produced on suitable land while the remaining 30% is grown on unsuitable land.

For sugarcane, it was found that about 15.02 million ha of land could potentially be considered for its production; this represent about 29.3% of Thailand's total surface. Based on land suitability levels, this breaks into 4.4 million ha of highly suitable land, 6.4 million ha of moderately suitable land and 4.2 million ha of lowly suitable for sugarcane production. As for cassava, these results indicate that low to medium land quality conditions seem to dominate the overall land quality conditions potential for sugarcane. When comparing the existing sugarcane plantation with the above zoning area map, it was observed that about 78% of the current (existing) area of cassava (1.4 Mha) is produced on suitable land while the remaining 22% is grown on unsuitable land.

4. Scenarios for Cassava and Sugarcane Production for Bioethanol

4.1 Scenario for cassava production

The scenario for maximized production of cassava was established based on the methodology framework identified in section 2, and following the next set of considerations:

- Theoretical potential area

  It corresponds to the area that meets the requirements for cassava production. Based on LDD information, only the areas that are highly suitable (S1) and moderately suitable (S2) were kept as part of this potential.

- Available potential area assessment

It corresponds to:

3) The area that is currently used for cassava plantation. This constitutes the based-line area of cassava plantation and this area will remain unchanged for as long as farmers do not switch to other crops.
4) The area that has a high potential for switching to cassava plantation. This corresponds to the additional area that could be used for cassava plantation. Within this, there are 2 sub-groups:
   - The area that is highly (S1) or moderately (S2) suitable for cassava and the area that is lowly (S3) or not (N) suitable for sugarcane but currently used for its production.
   - The area that is highly (S1) or moderately (S2) suitable for cassava but currently used for highland rice plantation.
5) The area that can be cultivated with environmental constraints : including, buffer zones around forest areas of at least 1km and buffer areas around rivers of 10m and 50m depending on the size of the river (2 main classes of river are considered).

- Technical potential area assessment

The technical potential area is the available potential area in which infrastructural considerations are included, i.e. location of cassava factories and road accessibility. This corresponds to the available potential area located within a 50km radius of a cassava-drier yard and accessible to vehicles via paved-road. Cassava dryer yards were focused on as they are the link between cassava producers and cassava consumers. Currently, there are 334 cassava-drier yards being operated in Thailand. This defines the maximum potential area for cassava production.

- Realistic potential area assessment

The realistic potential area was assessed by estimating the share of producers that could have an interest in switching from sugarcane or highland rice to cassava. This assessment was made by interviewing farmers and experts, and analyzing sugarcane production systems.

4.2 Scenario for sugarcane production

As for cassava, the scenario for maximized production of sugarcane was established based on the methodology framework identified in section 2, and following the next set of considerations:

- Theoretical potential area assessment

As for cassava, it corresponds to the area that meets the requirements for sugarcane production. Based on LDD information, only the areas that are highly suitable (S1) and moderately suitable (S2) were kept

- Available potential area assessment

It corresponds to:

1) The area that is currently used for sugar cane plantation. This constitutes the based-line area of sugarcane plantation and this area will remain unchanged for as long as farmers do not switch to other crops.
2) The area that has a high potential for switching to sugar cane plantation. This corresponds to the additional area that could be used for sugarcane plantation. Within this, there are 2 sub-groups:
    - The area that is highly (S1) or moderately (S2) suitable for sugarcane and the area that is lowly (S3) or not (N) suitable for cassava but currently used for its production.
    - The area that is highly (S1) or moderately (S2) suitable for sugarcane but currently used for highland rice plantation.
3) The area that can be cultivated with environmental constraints : including, buffer zones around forest areas of at least 1km and buffer areas around rivers of 10m and 50m depending on the size of the river (2 main classes of river are considered)

- Technical potential area assessment

The technical potential area is the available potential area in which infrastructural considerations are included, i.e. location of sugar mills and road accessibility. This corresponds to the available potential area located within a 50 km radius of sugar-mill factories and accessible to vehicles via paved-road. Currently, there are 51 of sugar-mill factories being operated in Thailand. This defines the maximum potential area for sugarcane production.

- Realistic potential area assessment

The realistic potential area was assessed by estimating the share of producers that could have an interest in switching from cassava or highland rice to sugarcane. This assessment was made by interviewing farmers and experts, and analyzing sugarcane production systems.

5. Assessment results of suitable areas for cassava and sugarcane

Based on the methodology and assumptions detailed previously, the results obtained for the cassava and sugarcane scenarios are reported in Tables 2 and 3.

Table 2 Assessment results of suitable areas for cassava plantations

	Area (million ha)
Theoretical potential area for cassava	6.800
- Highly and moderately suitable areas (LDD)	6.800
Available potential area for cassava	1.959
- Existing cassava crop	1.916
- Switching from sugarcane to cassava (scenario-based)	0.013
- Switching from highland rice to cassava (scenario-based)	0.192
- Environmental constraints (area switches from sugarcane to cassava)	-0.010
- Environmental constraints (area switches from highland rice to cassava area)	-0.152
Technical potential area for cassava	1.948
- Existing cassava crop	1.916
- Switching from sugarcane to cassava area	0.002
- Switching from highland rice to cassava area	0.030
Realistic potential area for cassava	1.934
- Existing sugarcane crop (100%)	1.916
- Switching from sugarcane (100%) and highland rice (53%)	0.018

Table 3 Assessment results of suitable areas for sugarcane plantations

	Area (million ha)
Theoretical potential area for sugarcane	10.800
- Highly and moderately suitable areas (LDD)	10.800
Available potential area for sugarcane	3.354
- Existing sugarcane crop	1.850
- Switching from cassava to sugarcane (scenario-based)	0.040
- Switching from highland rice to sugarcane (scenario-based)	3.219
- Environmental constraints (area switches from cassava to sugarcane)Environmental constraints (area switches from highland rice to sugarcane area)	-1.73
Technical potential area for sugarcane	2.553
- Existing sugarcane crop	1.850
- Switching from cassava to sugarcane area	0.015
- Switching from highland rice to sugarcane area	0.688
Realistic potential area for sugarcane	2.126
- Existing sugarcane crop (100%)	1.850
- Switching from cassava (100%) and switching from highland rice (38%)	0.276

Results regarding the realistic potential of cassava, as detailed in Table 2, indicate that there is little potential for expansion with only about 18,000 ha of additional land that could be converted to cassava. About 11% of this additional area is contributed by sugarcane and 89% by highland rice. This cassava expansion potential is equivalent to about 0.9% of the existing cassava plantation area.

For sugarcane plantation, focusing on the realistic potential, the results reported in Table 3 indicate that the potential for sugarcane expansion is greater than cassava. This additional area amounts to about 270,000 ha of land, 5% of which is contributed by cassava and 95% by highland rice. This is equivalent to about 15% of the existing sugarcane plantation area.

In either of the two cases, it is observed that highland rice provides the highest potential for cassava and sugarcane expansion; the potential for the switching of sugarcane plantation to cassava and vice-versa is minor. The limited potential for cassava and sugarcane expansion is in part due to the fact that there is a saturation of the land used for agricultural production in Thailand (the availability of uncultivated land is limited).

1. Introduction

1.1 Background

Energy consumption in Thailand has been continuously increasing over the years. In 2012, final energy consumption was about 73,316 ktoe, a 3.9% increase as compared to the previous year [1]. Petroleum products contribute the largest share of final energy consumption with about 48% of the total consumption. Over the past 15 years, biofuels have become the subject of increasing attention to substitute fossil fuels and so reduce import of crude oil, which Thailand heavily relies on, and therefore enhance national energy security. Among the liquid biofuels promoted for transportation in Thailand, bioethanol is one such renewable fuel. It can be produced from energy crops, including, sugarcane, cassava and Jatropha. Sugarcane and cassava are the main feedstock for such production in Thailand.

The total area of Thailand is 51.3 million ha. About 47% of this area is used for agricultural activity and 11% of the agricultural area is used for cassava and sugarcane production. Plantations of sugarcane and cassava are all around Thailand except in the southern region because of too high precipitation. In 2012, the cassava and sugarcane plantation areas covered about 1.4 million hectare and 1.3 million hectare respectively. The production of cassava and sugarcane was 29.4 million tons and 98.4 million tons respectively [2].

The climate and soil conditions of Thailand are quite suitable for agricultural production. This is notably so for cassava and sugarcane which plantations could potentially be expanded to enhance biofuel production. This study intends to assess areas of Thailand that are suitable for cassava and sugarcane plantation and identify scenarios of production that are appropriate to produce bioethanol.

1.2 Objective

1.2.1 Overall objective
To explore and identify in Thailand appropriate scenarios for cassava and sugarcane production for bioethanol

1.2.2 Specific objectives

- To review the current status of agricultural sector and bio-energy crop production in Thailand
- To identify areas that could be used for cassava and sugarcane plantations using GIS
- To identify the most relevant scenarios for suitable production of cassava and sugarcane for bioethanol based on experts interviews, field surveys with farmers and brainstorming sessions
- To quantify for each scenario of cassava and sugarcane production the theoretical, available and technical potential areas
- To determine the realistic potential area for both sugarcane and cassava based on the theoretical potential area quantified in the previous step and information collected from expert interviews and field surveys

1.3 Expected Outputs

- The different pathways of appropriate/sustainable cassava and sugarcane production for bioethanol
- The maximum potential of cassava and sugarcane feedstock production for bioethanol based on the appropriate/sustainable production pathways identified

2. Current status of agricultural sector and bioenergy crop production in Thailand

2.1 Status of agricultural sector in Thailand

Thailand is located in south-east Asia. The Kingdom covers an area of 51.31 million ha. Nearly half of Thailand's area (about 23.88 million ha) is used for agricultural activities. [2] In terms of economic productivity, in 2013, 8.3% of Thailand's gross domestic product (GDP) came from agricultural and agricultural-processing products. [3]

Based on records from the National statistical Office (NSO) for the year 2010, it is observed that 41% of Thai workers are involved in agricultural activities, including, farming, fishing, and forestry [4]. It is also noticed that most of the farmers have received elementary education and that more than half of them belong to a large family size category (at least 4-5 persons). The records also indicate that most farmers plant on their own land by hiring workers and that 90% of the farmers are independent, i.e. no contract-farming. However, it is important to notice that in the case of sugarcane farmers, there is usually existence of a contract-farming between a farm leader and a particular sugar factory (sugar mill). The farm leader signs a contract with the sugar factory to deliver cane as per a specified quota (quantity). In some cases, a large company may have a contract-farming to rent the land and also hires farmers to plant and deliver the feedstock to the company in order to avoid issues of lack of raw material. Details of the characteristics of Thai farmers are provided in Figures 2.1-2.5.

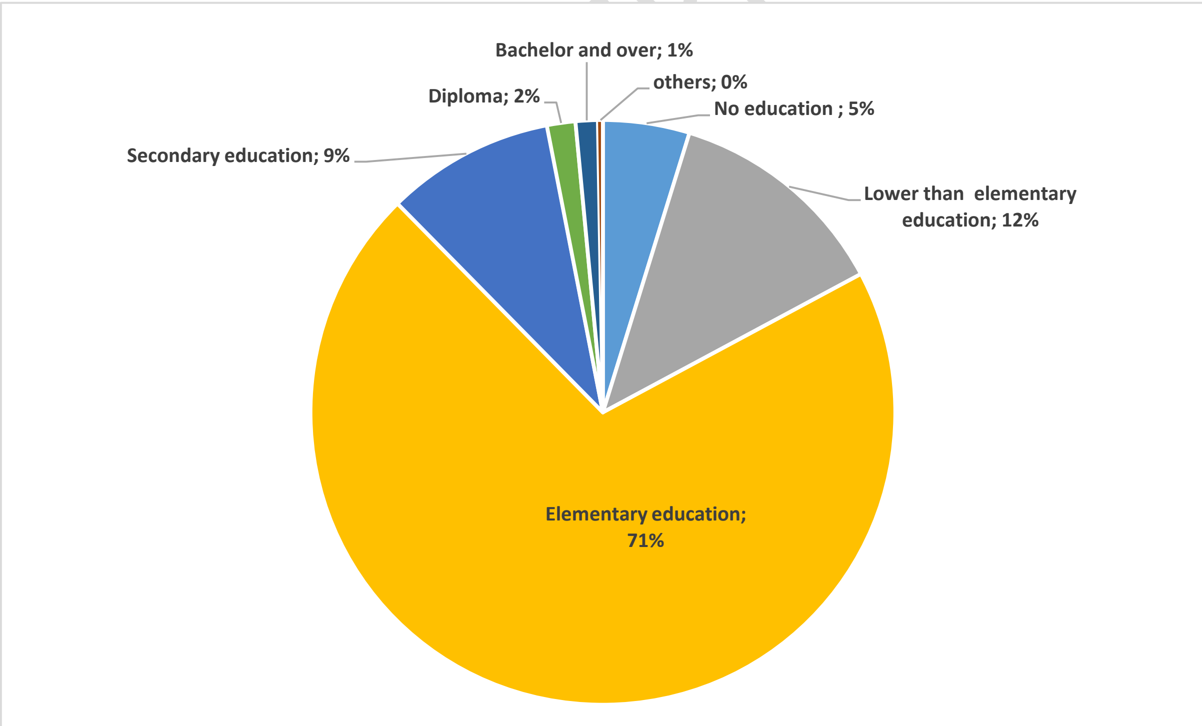


Figure 2.1 Share of farmers based on education level [4]

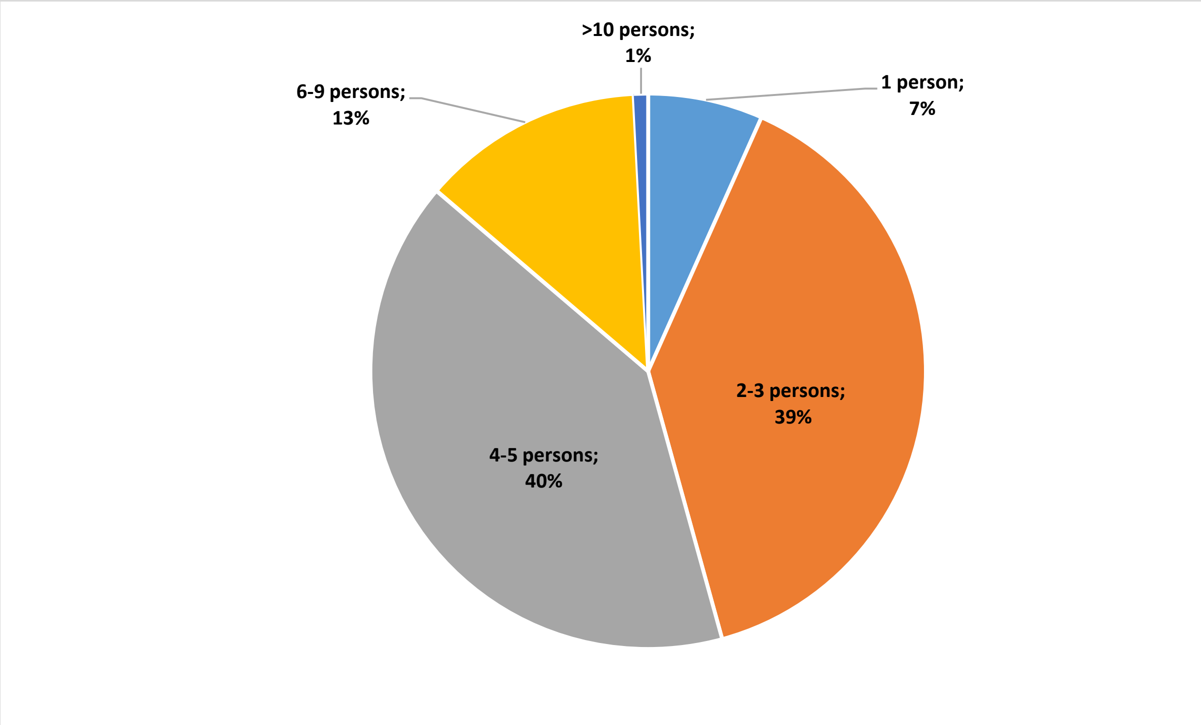


Figure 2.2 Share of farmers based on family size [4]

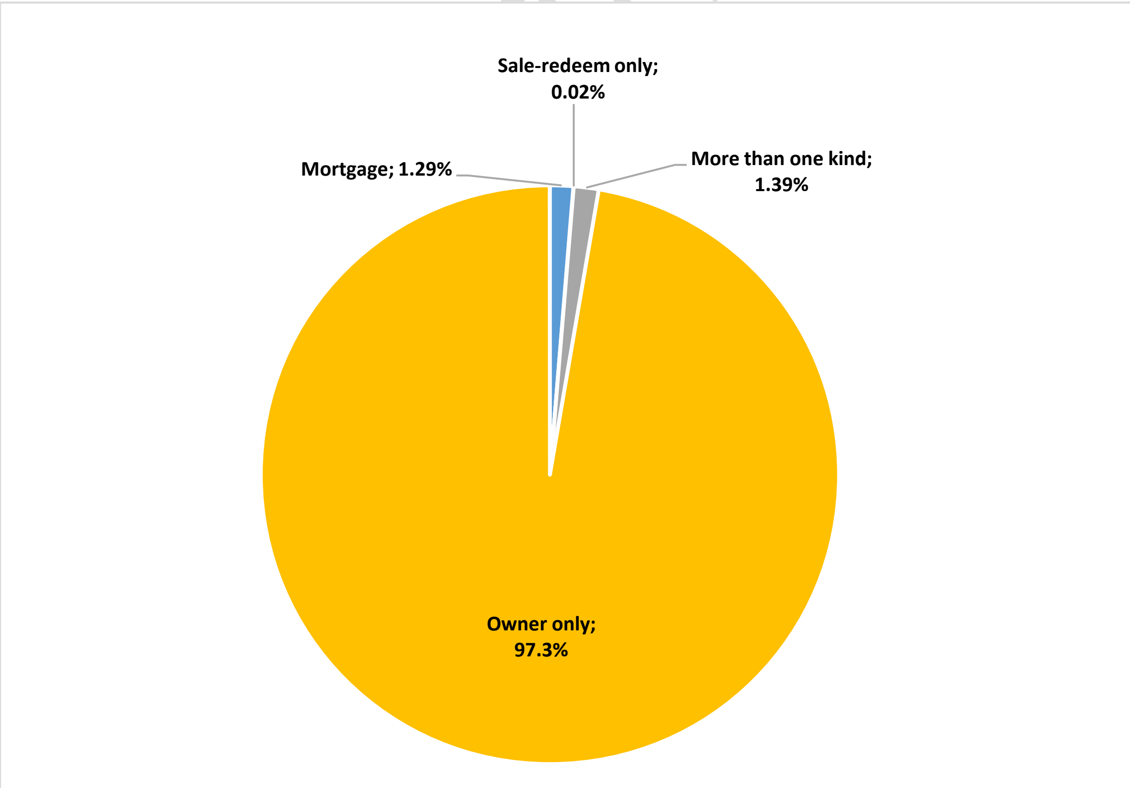


Figure 2.3 Share of farmers based on status of land tenure [4]

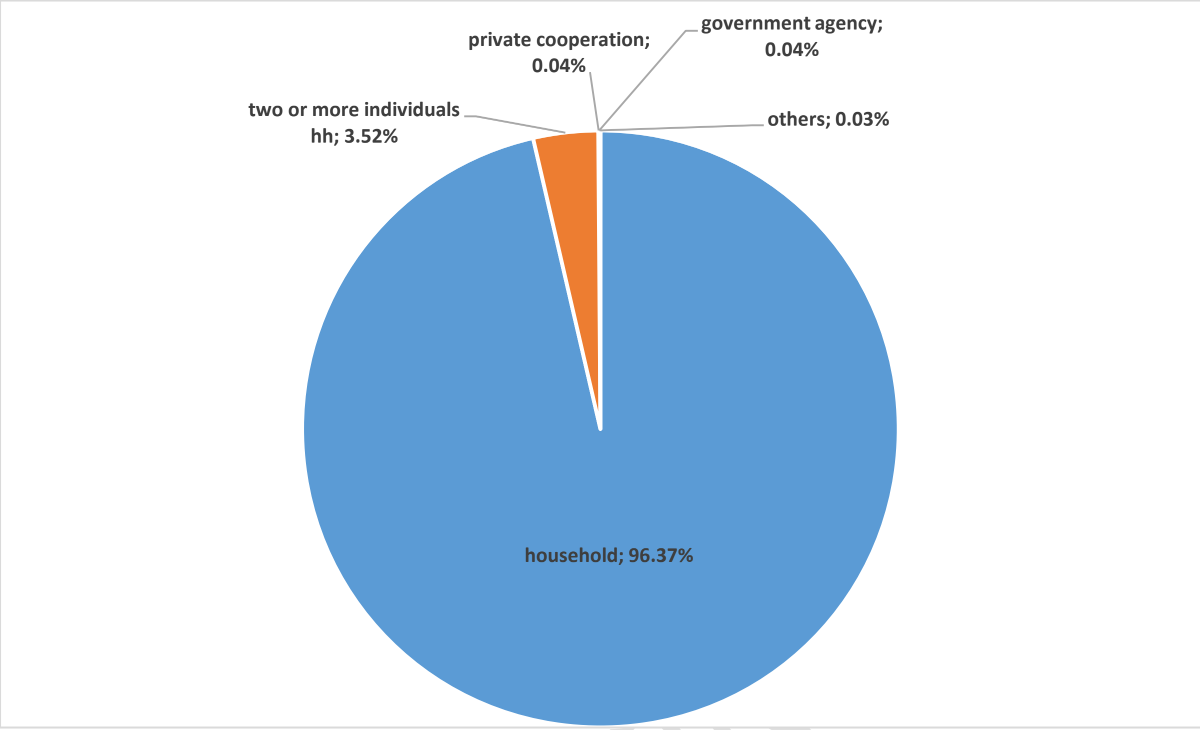


Figure 2.4 Share of farmers based on land holder status [4]

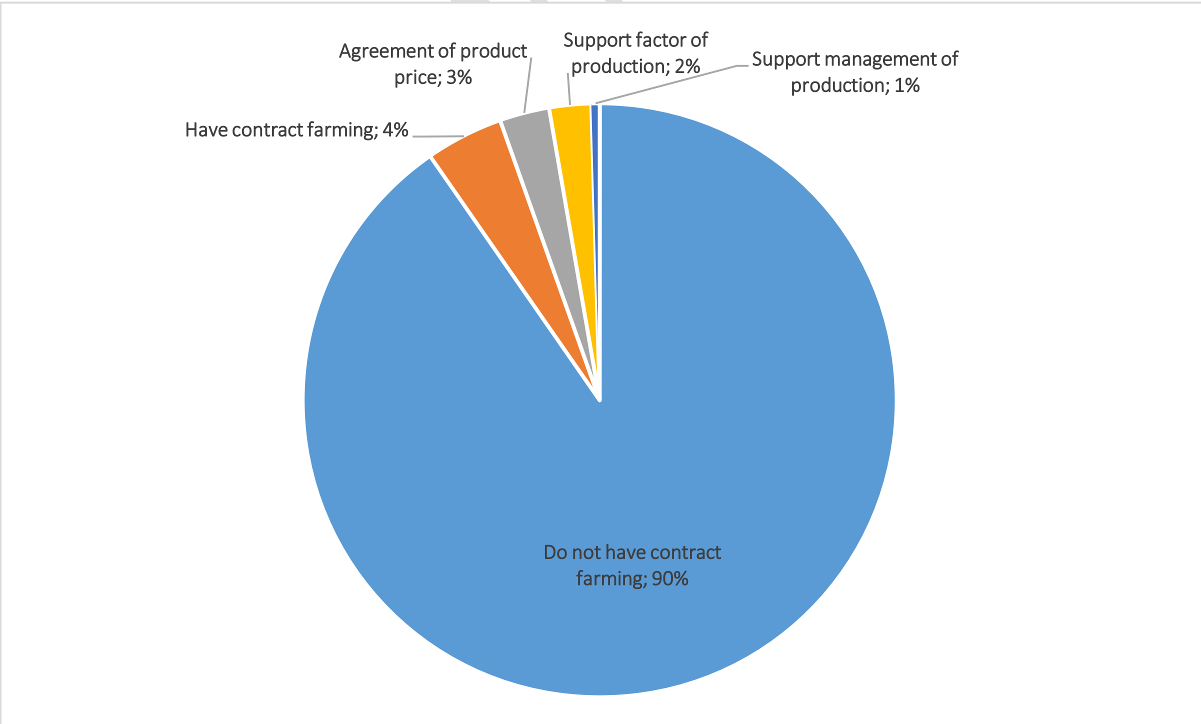


Figure 2.5 Share of farmers based on contract farming characteristics [4]

2.2 Current status of bioenergy crop production in Thailand

As an agricultural country, a variety of crops are being cultivated in Thailand, including, sugarcane, cassava, maize, sweet sorghum, palm oil, etc. In terms of energy crops, cassava and sugarcane are the most suitable for ethanol production.

2.2.1 Cassava

Thailand is the second largest exporter of cassava in the world (the first exporter is Nigeria.) In 2013, the export value of cassava and cassava products amounted to 95,692 million Thai baht (or about 3,190 million US dollars), 4th rank of the top 10 main agricultural products [5]. Cassava is mainly planted in the northeastern, central, and northern part of Thailand with a total harvested area covering 1.4 million ha (as sown in Figure 2.6). About 95% of the plantation area is harvested and the average yield of cassava roots is about 21.9 tonnes per ha. This yield is still lower than the one expected in the AEDP, i.e. 31.25 tonnes per ha. Cassava production is expected to increase with rising demand especially in the alcohol and ethanol industries. The trend of harvested area and yield of cassava during 2005 - 2014 are shown in Figure 2.7.

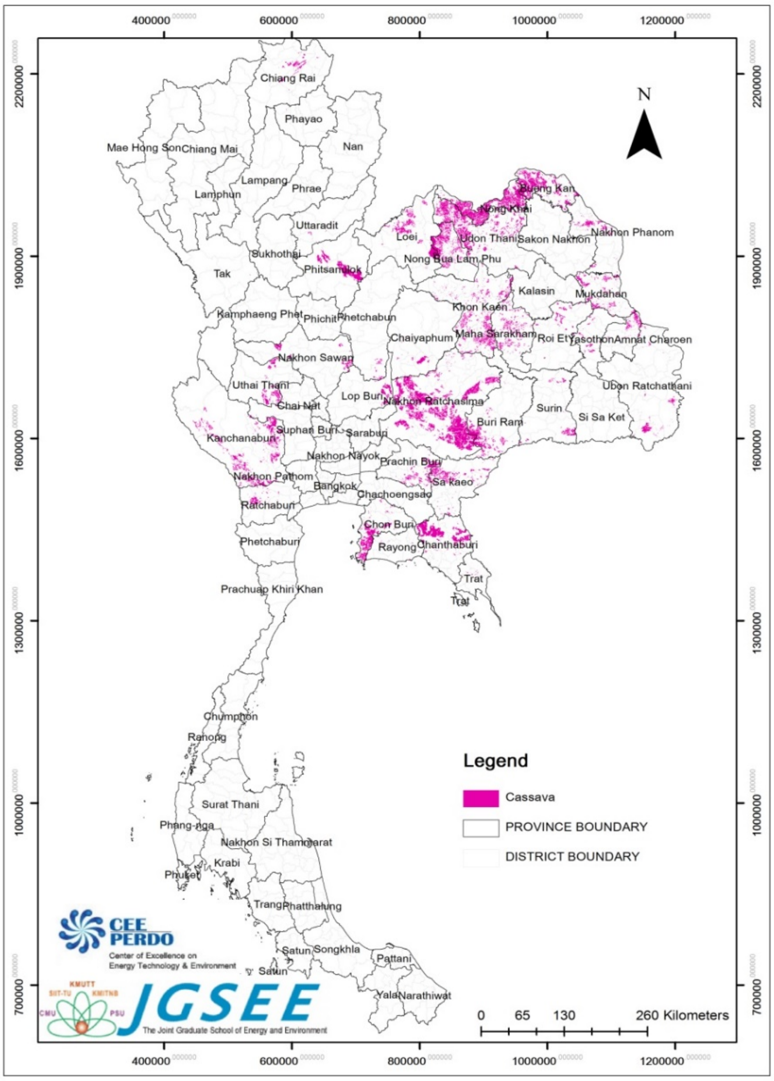


Figure 2.6 Coverage of cassava plantations in Thailand (year 2013)

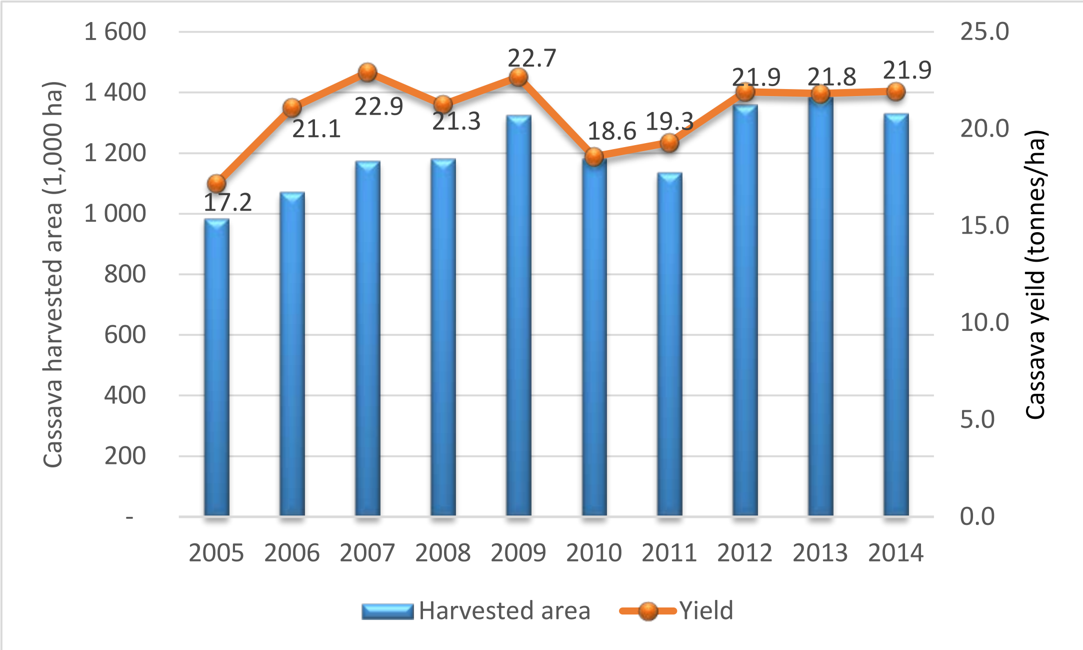


Figure 2.7 Harvested area and yield of cassava roots in Thailand during 2005-2014 [5]

Cassava is planted all year round. About 65% is planted at the beginning of the rainy season (over the period going from March to May) and about 35% during the dry season (during June to October). Most of the planting is done at the beginning of the rainy season as the starch content of the root becomes highest by the time of harvesting at the beginning of the winter season (around November up to January). The usual age for harvesting is between 9 to 12 months depending on the cassava price. In general, the largest share of the production (about 50% of the total production) occurs over the period January - March. An illustration of the temporal distribution of cassava production for the season 2012-2013 is given in Figure 2.8.

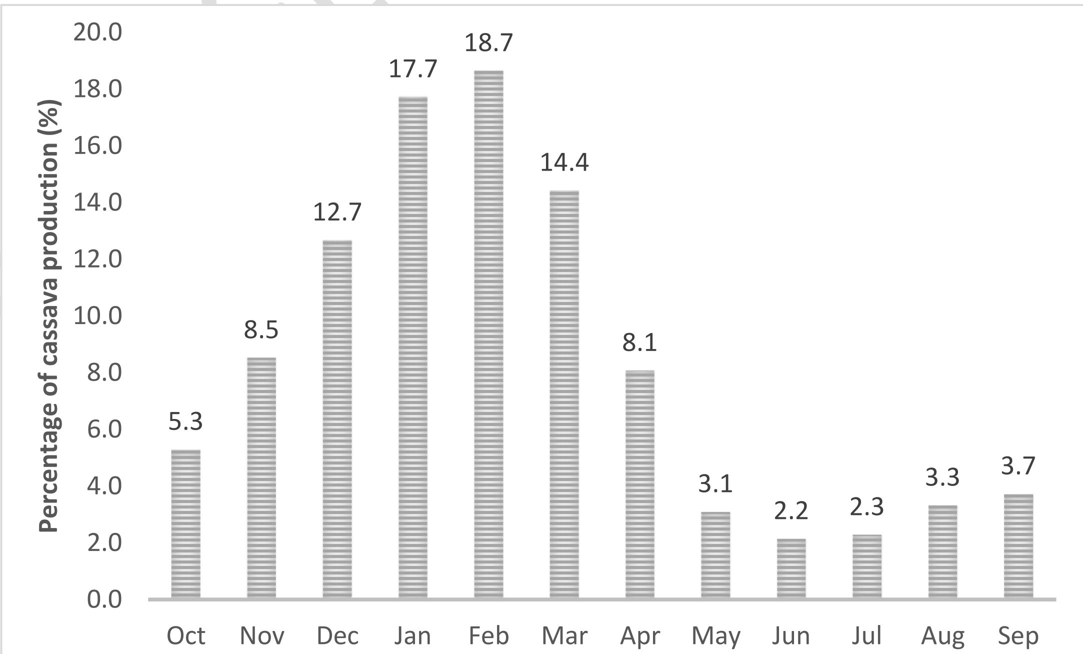


Figure 2.8 Temporal distribution of cassava production during 2012-2013 [2]

In Thailand, cassava roots are mainly processed into starch, cassava chips or pellets, and ethanol respectively. About 23% of the production is for domestic consumption in the form of flour (16%), animal feed (5%), and energy (2%). About 77% of the production is exported to countries, including, China, Japan, USA, South Korea, and Indonesia (only flour) in the form of cassava chips, pellets and flour. The flow of cassava and related products is summarized in Figure 2.9.

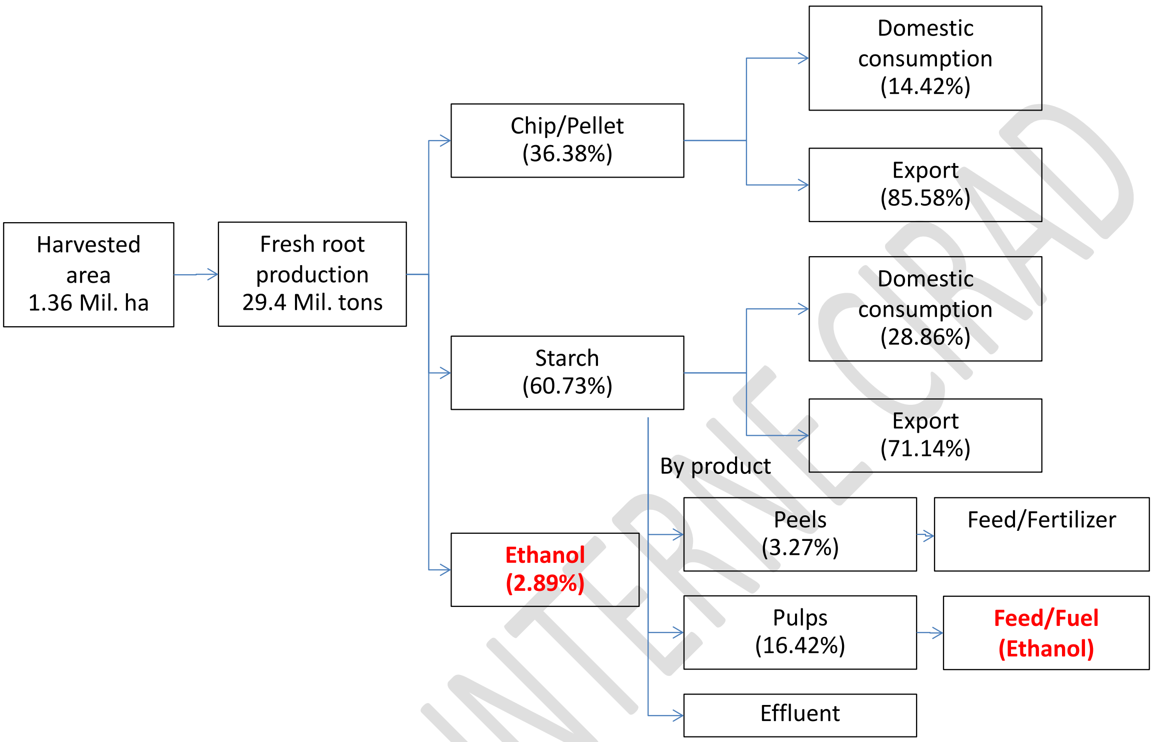


Figure 2.9 Flow of cassava and related products (year 2012) [6]

2.2.2 Sugarcane

Thailand is the second largest exporter of sugar and sugar products (the first exporter is Brazil.) In 2013, the export value of sugar and sugar products was about 67,717 million Thai baht (or about 2,257 million US dollars). Sugarcane is mainly planted in the northeastern, central, and northern part of Thailand with a total harvested area covering 1.3 million ha (2013) (see Figure 2.10). This was an increased figure as compared to the previous year as the price of sugarcane reached 1,000 baht per tonne (it was in the range 520 to 924 Thai baht per tonne in previous years, i.e. 2005-2012) whereas the other crops, including, maize and cassava, had lower returns [5]. The yield of sugarcane is about 75.7 tonnes per ha; this is lower than the 93.75 tonnes per ha targeted in the AEDP. Sugarcane production is expected to increase in accordance with the expansion of the food and fuel industry, and its market price. The trend of harvested area and yield of sugarcane production during 2005-2014 are shown in Figure 2.11.

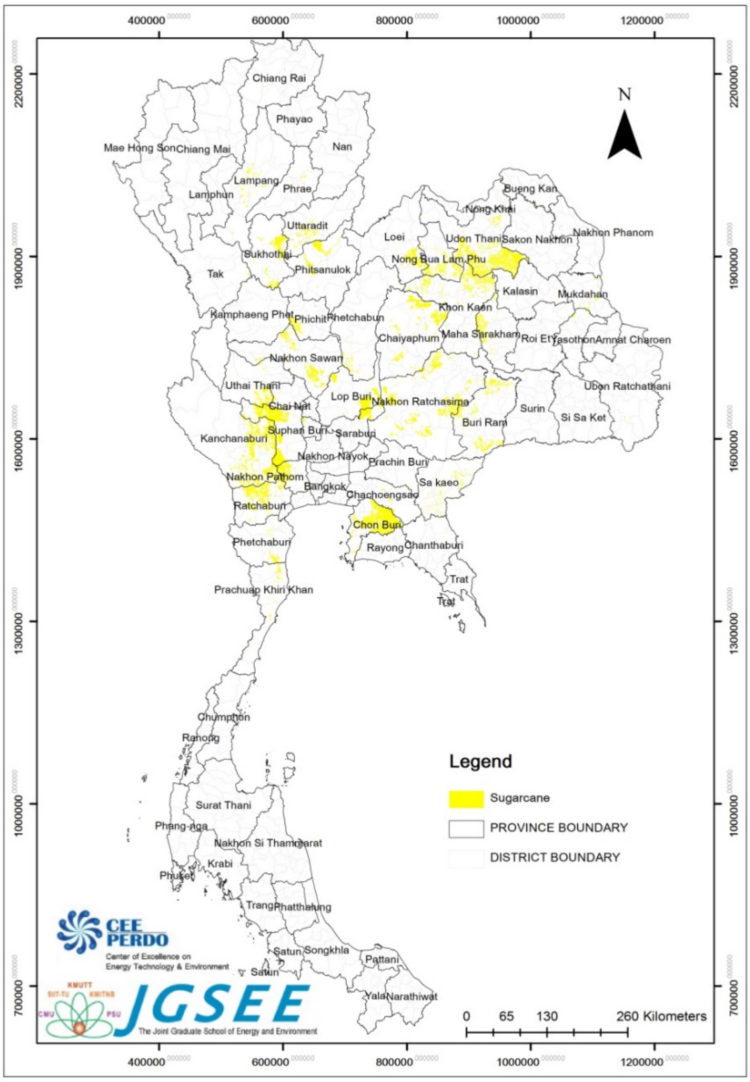


Figure 2.10 Coverage of sugarcane plantations (year 2013)

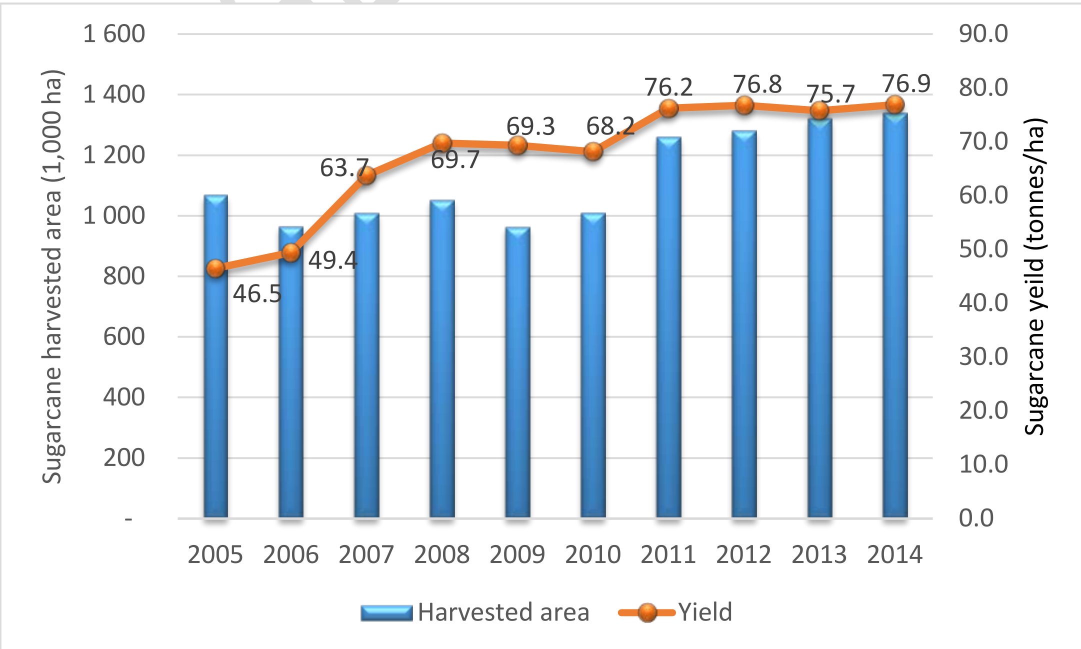


Figure 2.11 Harvested area and yield of sugarcane in Thailand [5]

The seasonality of sugarcane plantation varies by region. Sugarcane is planted during October to November in the northeastern region, during November to February in the central region and during December to May in the northern region. The usual age for harvesting is about 10 to 14 months depending on the starting date of the cane crushing season which is set by the Office of the Cane and Sugar Board (OCSB). All sugar mill factories are under the OCSB. There are currently 51 sugar mill factories in operation. All sugarcane farmers are members of the sugarcane grower association which is under the supervision of the OCSB. The starting period of the cane crushing season, the amount of cane crushed, and the price of sugarcane depend on the announcement from the OCSB. Normally, the cane crushing season starts at the beginning of November or December and lasts up to the end of April. During the cultivation season of 2012-2013, the OCSB announced the beginning of the cane crushing season to be on 15 November 2012 with a total sugar production of 94.64 million tonnes; with different quota of production for each region of the country. The temporal distribution of sugarcane production over the season 2012-2013 is shown in Figure 2.12.

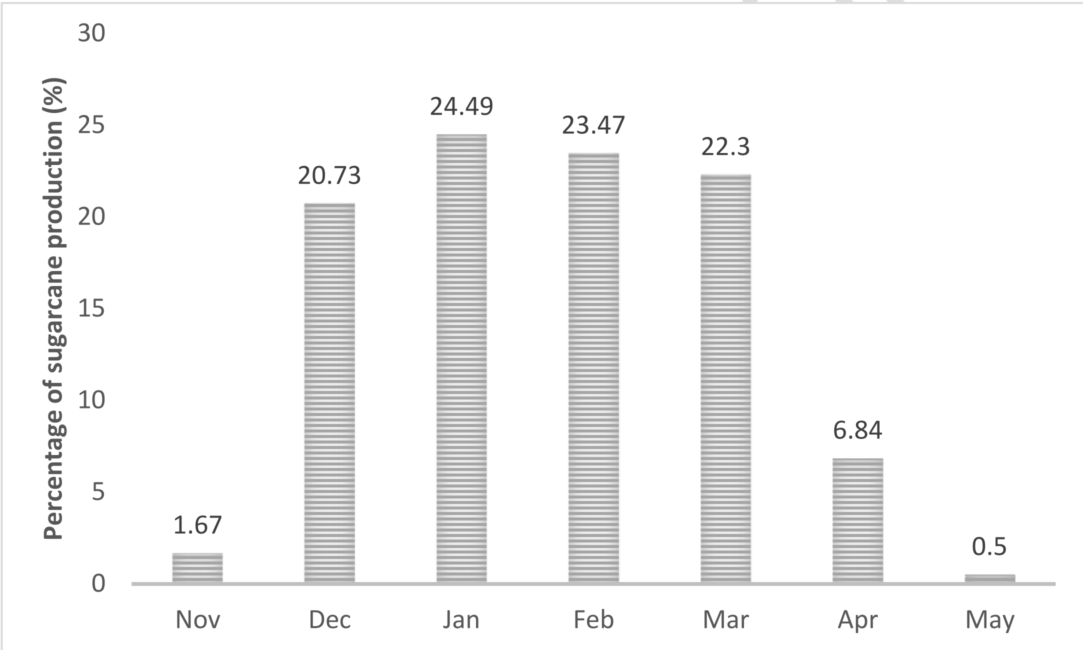


Figure 2.12 Temporal distribution of sugarcane production over the season 2012-2013 [2]

All of the sugarcane is processed into sugar with about 70% of the total production being exported. Bagasse and molasses are major by-products of the sugar production process. Bagasse is mainly used as fuel for power production. Molasses are mainly used for ethyl alcohol or ethanol production which can be used in the food and fuel industry. The Flows of sugarcane and related products are summarized in Figure 2.13.

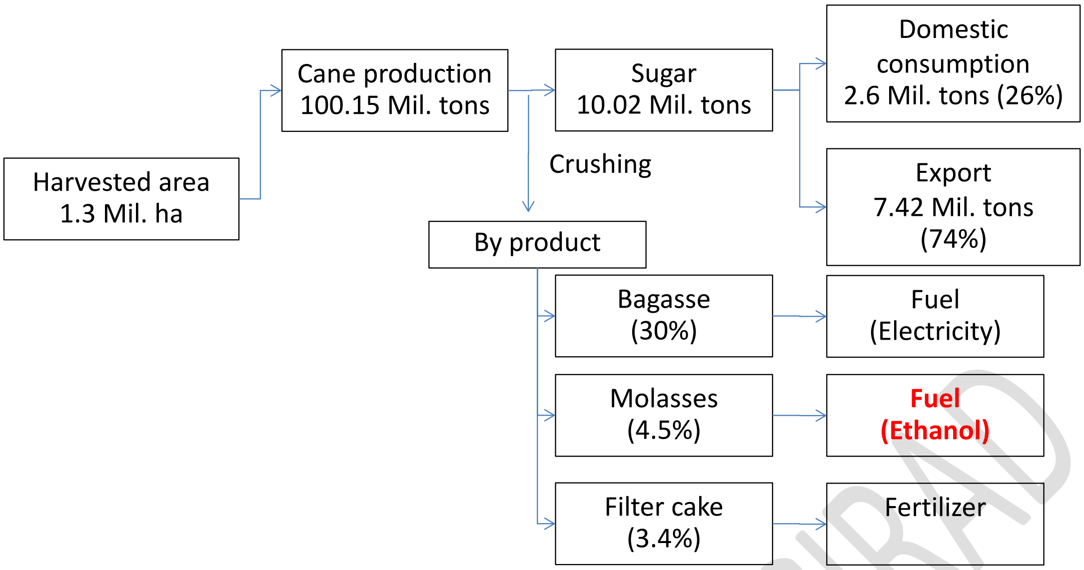


Figure 2.13 Flow of sugarcane and related products (year 2012) [6]

2.3 Agricultural zoning area

The Land Development Department (LDD) of Thailand has developed a project entitled "Zoning area of main economical crop of Thailand". The objective of this project is to assess the zoning area of 5 main economic crops of Thailand, including rice, sugarcane, cassava, para-rubber, and palm oil by assessing the suitability of land to meet a particular crop requirement (in terms of climatic and soil conditions). For each crop, the suitability of area is ranked into 4 levels, including, highly suitable area, moderately suitable area, lowly suitable area, and unsuitable area. The details of the zoning area of cassava and sugarcane are as detailed below:

2.3.1 Zoning area of cassava

Based on the land quality conditions of LDD for cassava production (as demonstrated in Table 2.1), it has been found that the total land area that could potentially be considered for cassava production amounts to 11.65 million ha (ignoring what that land may currently be used for); this is about 22.7% of Thailand's total surface. This coverage is referred in this section as "cassava zoning area" and shown in Figure 2.14. It is observed from this figure that about 2.5 million ha (or 22% of this total cassava zoning area) is highly suitable for cassava production (see crimson color), 4.3 million ha (or 37% of the total cassava zoning area) is moderately suitable (see red color), and 4.7 million ha (or 41% of cassava zoning area) is lowly suitable (see light-pink color). These results indicate that most of the potential areas identified would provide low to medium land quality conditions for cassava production and therefore soil quality improvement would be important to enhance root yields.

Table 2.1 Land quality suitability classes for cassava

Land quality	Diagnostic factor	Crop requirement in each level			
		Highly suitable (S1)	Moderately suitable (S2)	Lowly suitable (S3)	Unsuitable
Water availability	Annual rainfall (mm/yr)	1,100-1,500	900—1,100 1,500-2,500	500-900 2,500-4,000	<500 >4,000
Physical property of soil	Soil depth (cm)	>100	50-100	25-50	<25
	Soil texture	C, L, SCL, SiL, Si,CL,L,SL,SiCL	LS	SiC	C,G,SC,AC,S
Chemical property of soil	pH	6.1-7.3	7.4-7.8 5.1-6.0	7.9-8.4 4.0-4.5	>8.4 <4.0
	N (%)	>0.2	0.1-0.2	<0.1	-
	P (ppm)	>25	6-25	<6	-
	K (ppm)	>60	30-60	<30	-

Remark: SL = Sandy loam, C = Clay (%clay<60), LS = Loamy sand, SC = Sandy clay, C = Clay (%clay>60), S = Sand, G = Gravel soil, SC = Slope complex, AC = Alluvial complex; Source: [10]

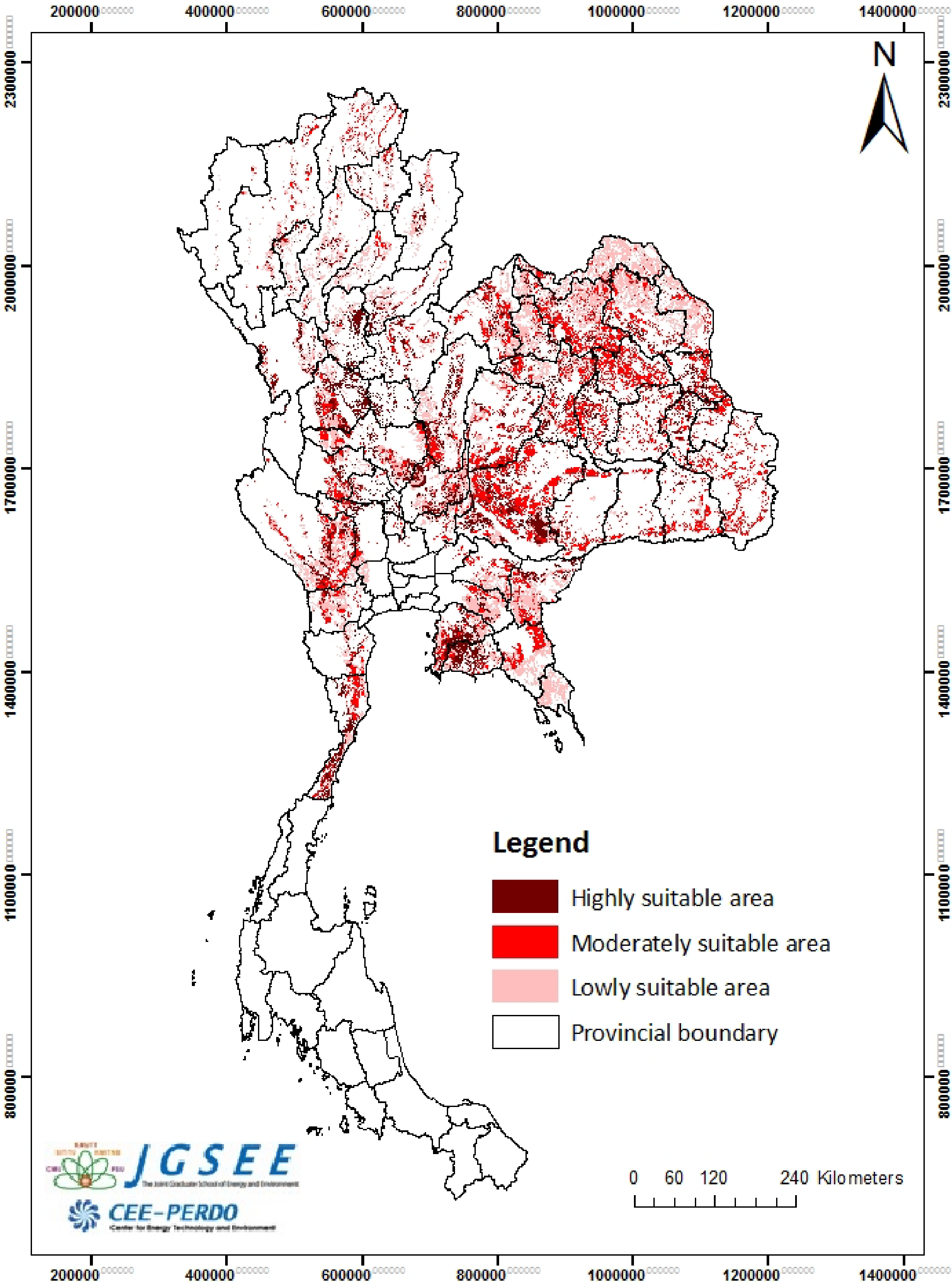


Figure 2.14 Cassava zoning area

2.3.2 Zoning area of sugarcane

Based on the land quality conditions of LDD for sugarcane production (as demonstrated in Table 2.2), it has been found that the total land area that could potentially be considered for sugarcane production amounts to 15.02 million ha (ignoring what that land may currently be used for); this is about 29.3% of Thailand's total surface. This coverage is referred in this section as "cassava zoning area" and shown in Figure 2.15. It is observed from this figure that about 4.4 million ha (or 30% of this total sugarcane zoning area) is highly suitable for sugarcane production (see crimson color), 6.4 million ha (or 42% of the total sugarcane zoning area) is moderately suitable (see red color), and 4.2 million ha (or 28% of sugarcane zoning area) is lowly suitable (see light-pink color). These results indicate that most of the potential areas identified would provide medium to low land quality conditions for sugarcane production and therefore soil quality improvement would be important to enhance cane yields.

Table 2.2 Land quality suitability classes for sugarcane

Land quality	Diagnostic factor	Crop requirement in each level			
		Highly suitable (S1)	Moderately suitable (S2)	Lowly suitable (S3)	Unsuitable
Water availability	Annual rainfall (mm/yr)	1,600-2,500	1200-1600	900-1200	< 900
Physical property of soil	Soil depth (cm)	>100	50-100	25-50	<25
	Soil texture	C, L, SCL, SiL, Si, CL, L	SiCL, SL	SiC, LS	C, G, SC, AC, S
Chemical property of soil	pH	6.1-7.3	7.4-7.8 5.1-6.0	7.9-8.4 4.0-4.5	>8.4 <4.0
	N (%)	>0.2	0.1-0.2	<0.1	-
	P (ppm)	>25	6-25	<6	-
	K (ppm)	>60	30-60	<30	-

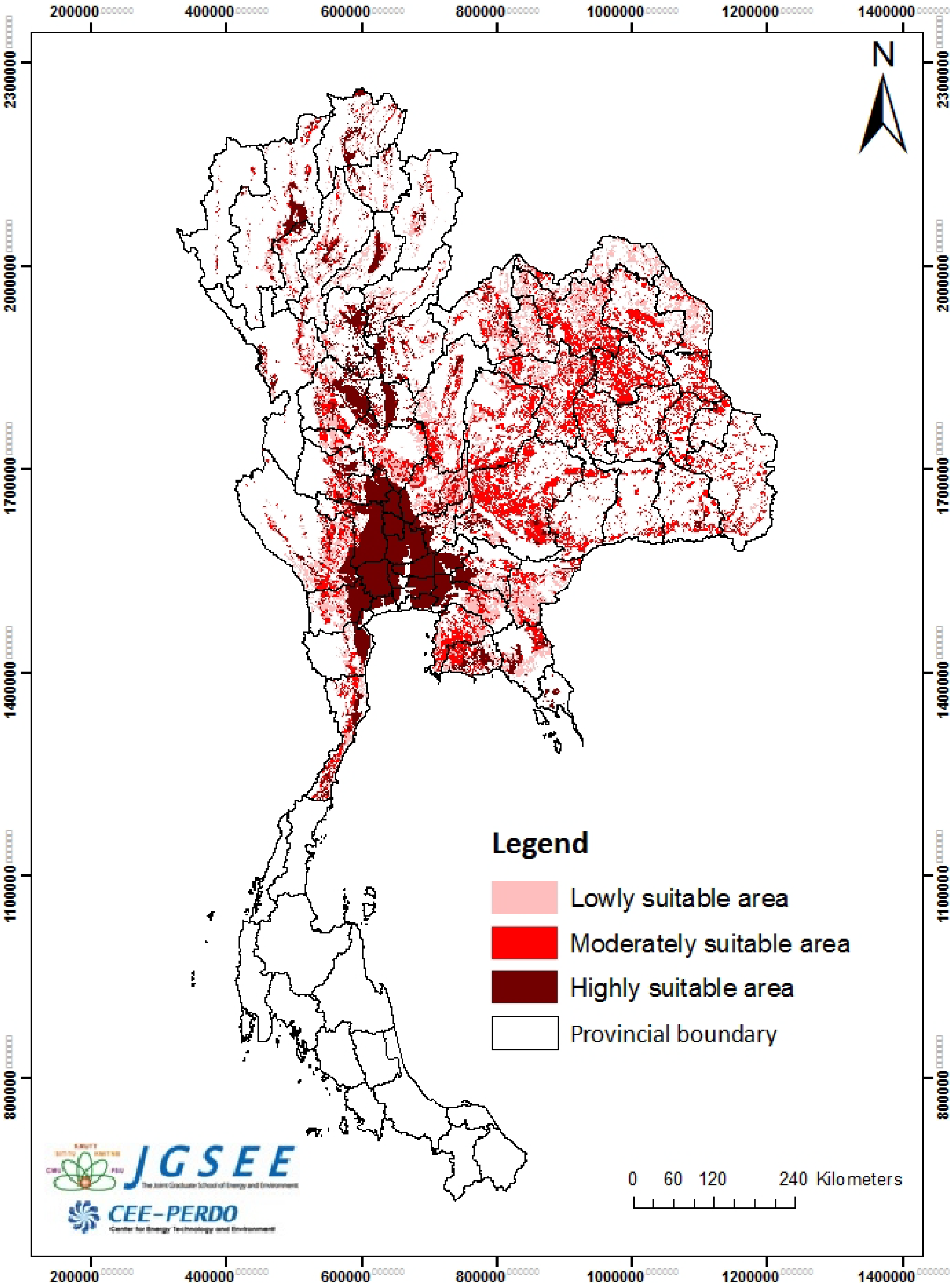


Figure 2.15 Sugarcane zoning area

2.4 Current status of ethanol production and consumption

2.4.1 Ethanol production

In 2013, Thailand produced 949.1 million litres of ethanol or about 2.9 million litres per day which represents about 69.3% of the full production capacity. The raw materials for ethanol production are molasses, cane juice, and cassava with a share of 66%, 6%, and 28% respectively. Thailand has 21 ethanol factories (as demonstrated in Figure 2.16) with a total production capacity of 4.2 million litres per day, including 14 factories that are molasses-based, 1 factory that is cane juice-based, and 6 factories that are cassava-based. An additional 3 ethanol factories are being constructed providing a combined extra 1.3 million litres per day ethanol to the current total production capacity. The amount of feedstock and volume of ethanol produced for the years 2011, 2012 and 2013 are detailed in Table 2.3. The locations of the ethanol factories are shown in Figure 2.16.

Table 2.3 Amount of feedstock and volume of ethanol produced during 2011-2013

Year	Amount of feedstock (million tonnes)			Volume of ethanol production (million litres of ethanol)			
	Molasses	Cane juice	Cassava	Molasses-based	Cane juice-based	Cassava-based	Total
2011	1.6	0.5	0.6	381.4	36.5	102.6	520.5
2012	2.2	0.6	0.5	531.8	49.0	74.7	655.5
2013	2.6	0.8	1.7	627.0	56.9	265.2	949.1

Source: [7]

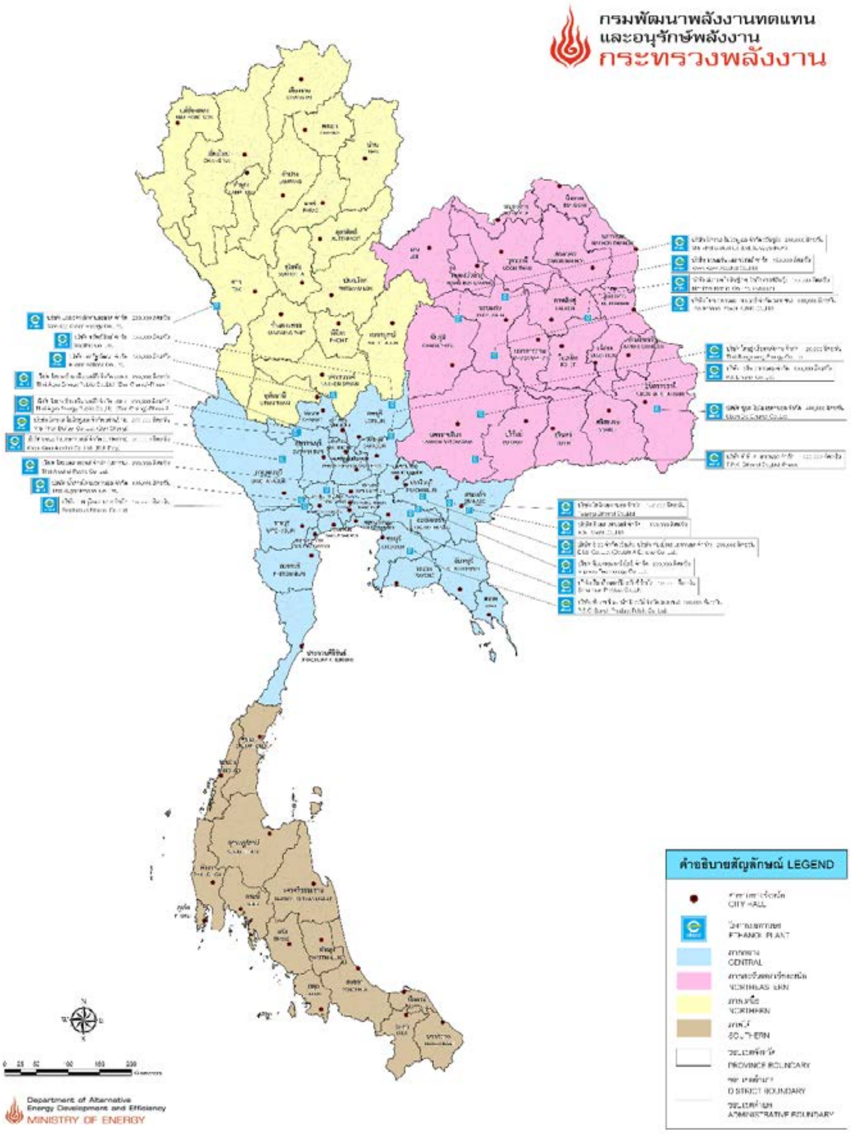


Figure 2.16 Locations of ethanol factories in Thailand (year 2013) [7]

2.3.2 Ethanol consumption

Ethanol is used as a fuel in transport engine by blending it with gasoline; it is referred to as gasohol. Gasohol in Thailand was originally introduced by His Majesty the King Bhumibol in 1985. Currently in Thailand there are 4 types of gasohol blends, including, E10-gasohol 95 (a blend of 90% gasoline 95 and 10% ethanol), E10-gasohol 91 (a blend of 90% gasoline 91 and 10% ethanol), E20 (a blend of 80% gasoline and 20% ethanol), and E85 (a blend of 15% gasoline and 85% ethanol). In 2013, the amount of gasohol consumption was about 7,469 million litres, an increase of about 67% as compared to the previous year; this was mainly because of the termination of the sale of octane 91 regular gasoline at the beginning of 2013. This resulted in increasing the annual demand for ethanol to 948.7 million litres or about 2.6 million litres per day. About 85% of ethanol is used in the form of E10 (both E10-gasohol 91 and E10-gasohol 95), 13% as E20, and 2% as E85. The ethanol demand was expected to reach 3 million litres per day. Fuel consumption in 2011, 2012 and 2013 is detailed in Table 2.4.

Table 2.4 Fuel consumption during 2011-2013

	Fuel Consumption (million litres)		
	Yr 2011	Yr 2012	Yr 2013 [p]
Gasoline	3,119	3,250	763
Regular (octane 91)	3,077	3,208	147
Premium (octane 95)	41	42	616
Gasohol	4,213	4,455	7,469
Gasohol E10 -octane 91	1,860	2,121	3,337
Gasohol E10 -octane 95	2,122	1,931	3,029
Gasohol E20	222	367	962
Gasohol E85	9.10	36	141

Remark: Year 2013 is predicted by DEDE; Source: [7]

2.3.3 Export

In the year 2013, the volume of ethanol exported was about 63.7 million litres. Compared with the previous year, the volume of ethanol exported had decreased by 77%. This was because of the increasing demand for domestic consumption due to the termination of the sales of octane 91 regular gasoline.

2.3.4 Ethanol stock

At the end of 2013, the ethanol stock was about 87.5 million litres which represents a 178.5% increase as compared to the previous year (as a result of the high production to serve the high demand for bioethanol). Based on the ethanol demand, this stock can only satisfy the demand for about 30 days.

2.3.5 Cost and price

In 2013, the cost to produce ethanol was in the range 21.22 – 21.87 Thai baht per litre depending on the raw material used. The average cost to produce molasses ethanol was about 21.87 Thai baht per litre (the cost of molasses was 3.17 Thai baht per Kg) while the cost to produce cassava ethanol was about 21.22 Thai baht per litre (the cost of cassava was 2.13 Thai baht per Kg). The ex-refinery price of ethanol for the same year was about 25.40 Thai baht per litre. In comparison to the world market price of ethanol, the price of ethanol in Thailand is observed to be higher than in other countries. Indeed, the average world market price of ethanol was only about 20.15 to 23.25 Thai baht per litre (or about 0.65-0.75 US dollar per litre).

The situation of ethanol in Thailand over the years 2011 to 2013 is summarized in Table 2.5.

Table 2.5 Situation of ethanol production in Thailand during 2011 to 2013

	Yr 2011	Yr 2012	Yr 2013
No. of ethanol factories	19	20	21
- molasses	13	14	14
- sugarcane	1	1	1
- cassava	5	5	6
Production capacity (million litres/day)	2.9	3.3	4.2
- molasses	2.1	2.3	2.6
- sugarcane	0.2	0.2	0.2
- cassava	0.8	0.8	1.4
Production (million litres/day)	1.7	1.8	2.9
- molasses	1.1	1.4	1.9
- sugarcane	0.3	0.1	0.2
- cassava	0.3	0.3	0.8
Domestic Consumption (million litres/day)	1.2	1.4	2.6
Export (million litre)	167.0	276.2	63.7
Stock (@ December) (million litres)	68.9	31.5	87.5
Production cost (Thai baht/litre)			
- molasses-ethanol	23.95	18.97	21.87
- cassava-ethanol	25.77	20.18	21.22
Selling price (Thai baht/litre)	19.00-22.50	19.50-20.25	21.50-27.50

Source: [8]

2.4.5 Thailand ethanol policy

As of 2012, final energy consumption in Thailand was about 73,316 ktoe with only 7.7% contributed by renewable energy. The Ministry of Energy launched a plan to increase the share of renewable and alternative energy to reach 25% of Thailand's total energy consumption in the next 10 years (AEDP: 2012-2021) as shown in Figure 2.17. Renewable and alternative energies in the AEDP 2012-2021 include: solar, wind, hydro, biomass, geo, and tidal wave. For bioethanol, the target is set at 9 million litres per day to be gradually achieved by 2021 (the current consumption is only about 2.6 million litres per day). The bioethanol development plant can be classified into 2 main sides: the supply side and the demand side.

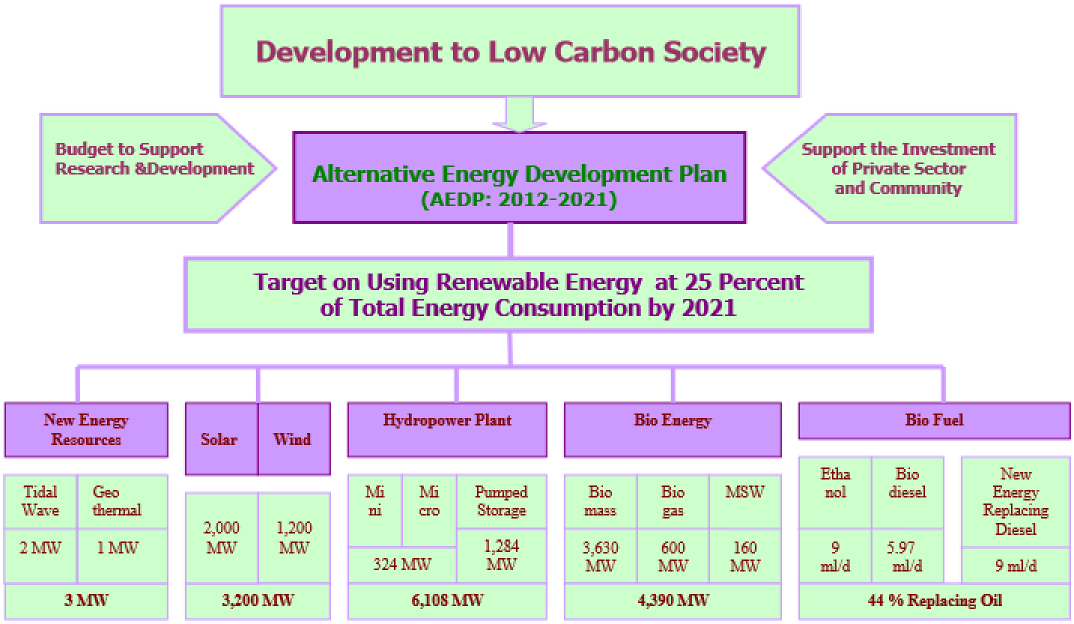


Figure 2.17 Alternative energy development plan (AEDP 2012-2021) [9]

Supply side:

1) To increase the cassava and sugarcane yield to more than 5 tonnes per rai (about 31.25 tonnes per ha) and 15 tonnes per rai (or about 93.75 tonnes per ha) respectively by 2021. The current situation and targets are summarized in Table 2.6.
2) Support alternative crops, e.g. sorghum, etc.

Table 2.6 Current situation and targets of ethanol feedstock production

	Area (million ha)		Yield (tonnes per ha)	
	AEDP Plan [a]	Current Situation [b]	AEDP Plan [a]	Current Situation [b]
Cassava	1.12	1.33	31.25	21.87
Sugarcane	1.12	1.34	93.75	76.87

Source: [a] [9] , [b] [5]

Demand side:

1) Terminate the sales of octane 91 regular gasoline by October 2012
2) Subsidize E20 gasohol from the state oil fund, to be 3.0 baht/liter cheaper than Octane 95 gasohol
3) Incentive for gasoline stations to expand the E20 gasohol sales by giving 0.5 baht/liter
4) Support the manufacturing of eco-car and flex-fuel vehicles (FFV) which are compatible with E85 gasohol by reducing excise tax for automobile manufacturers by 30,000 baht/vehicle for eco-car and 50,000 baht/vehicle for FFV
5) Funding research on adapting old engines and motorcycles to run on higher blend of ethanol, which would enhance the ethanol demand
6) Liberalize the ethanol laws and regulation, which is still governed by the Liquor Act

3. Description of selected scenarios for maximizing the production areas of cassava and sugarcane

The scenarios for maximizing the production of cassava and sugarcane were developed based on the assessment of maximum “suitable switchable” area that can be used for planting the above mentioned bioethanol crop feedstock. The “suitable switchable” area is defined as the area that could be switched from current crop use to cassava or sugarcane plantation based on land suitability considerations (soil conditions and water availability meeting the growth requirement of cassava and sugarcane). The current crop focuses on cassava, sugarcane, and highland rice only. Highland rice is considered as a switchable area according to the policy of the Thai government which is promoting the plantation of sugarcane in highland rice areas. Since, the soil conditions requirements for cassava and sugarcane production are fairly similar, it is possible that highland rice be located on land which soil conditions are suitable for either crop. In that case, sugarcane would be selected as the first priority for the switch.

The assessment of the maximum potential area that could be used for cassava and sugarcane production in Thailand is based on the following methodological process: (1) The “theoretical potential area” is identified. It corresponds to the area that meets the requirements for cassava or sugarcane cultivation. This information is processed based on soil suitability and water availability criteria for cassava and sugarcane as defined by the Land Development Department (see section 2.4). (2) Based on (1), the “available potential area” is identified. It corresponds to the

1. area that is currently used for cassava (or sugarcane) cultivation
2. area that can be switched to cassava (or sugarcane) and that fits environmental constrains (buffer zones)

(3) Based on (2), the “technical potential area” is identified. In this step, infrastructure considerations (road network and location of cassava factories and sugar mills) are taken into consideration to narrow down the land area that can technically be considered for cassava and sugarcane production. This identified the maximum potential area that could be used for cassava and sugarcane production.

(4) Based on (3) the “realistic potential area” is identified. *It corresponds to* the technical potential area that stakeholders could operate in accordance with their capacity to switch from a crop to another.

3.1 Cassava

The assessment framework followed to evaluate the maximum area that could be used for cassava production is shown Figure 3.1. The assessment is composed of 4 main steps as detailed below:

3.1.1 Theoretical potential area assessment

The theoretical potential area is the area that meets the requirements for cassava production.

From the LDD information, only the areas that are highly suitable and moderately suitable are kept.

3.1.2 Available potential area assessment

It corresponds to:

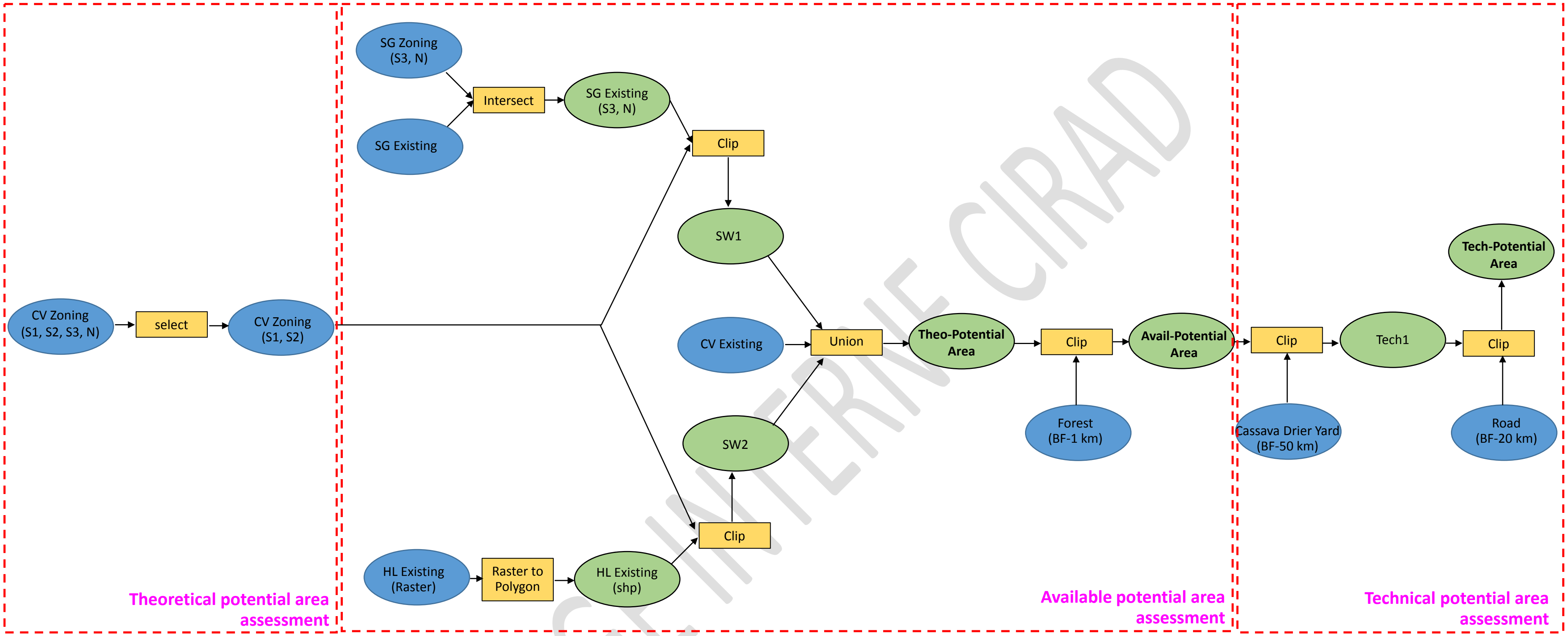
6) The area that is currently used for cassava plantation. This constitutes the based-line area of cassava plantation and this area will remain unchanged for as long as farmers do not switch to other crops.
7) The area that has a high potential for switching to cassava plantation. This corresponds to the additional area that could be used for cassava plantation. Within this, there are 2 sub-groups:
   - The area that is highly (S1) or moderately (S2) suitable for cassava and the area that is lowly (S3) or not (N) suitable for sugarcane but currently used for its production.
   - The area that is highly (S1) or moderately (S2) suitable for cassava but currently used for highland rice plantation.
8) The area that can be cultivated with environmental constraints : including, buffer zones around forest areas of at least 1km and buffer areas around rivers of 10m and 50m depending on the size of the river (2 main classes of river are considered)

3.1.3 Technical potential area assessment

The technical potential area is the available potential area in which infrastructural considerations are included, i.e. location of cassava factories and road accessibility. This corresponds to the available potential area located within a 50 km radius of a cassava-drier yard and accessible to vehicles via paved-road. Cassava dryer yards are focused on as they are the link between cassava producers and cassava consumers. Currently, there are 334 cassava-drier yards being operated in Thailand. This defines the maximum potential area for cassava production.

3.1.4 Realistic potential area assessment

The realistic potential area is assessed estimating the share of producers that can have an interest to switch from sugarcane or highland rice to cassava. This assessment is made by interviewing farmers and experts, and analyzing sugarcane production systems.



Where:

SG Zoning	= Area suits for sugarcane growth	SW	= Switchable area
SG Existing	= Area currently plants sugarcane	Theo-Potential Area	= Theoretical potential area
		Avail-Potential Area	= Available potential area

Figure 3.1: Assessment framework for cassava

3.2 Sugarcane

The assessment framework followed to evaluate of the maximum area that could be used for sugarcane production is shown in Figure 3.2. The assessment is composed of 4 main steps as detailed below:

3.2.1 Theoretical potential area assessment

The theoretical potential area is the area that meets the requirements for sugarcane production.

From the LDD information, only the areas that are highly suitable and moderately suitable are kept

3.2.2 Available potential area assessment

It corresponds to:

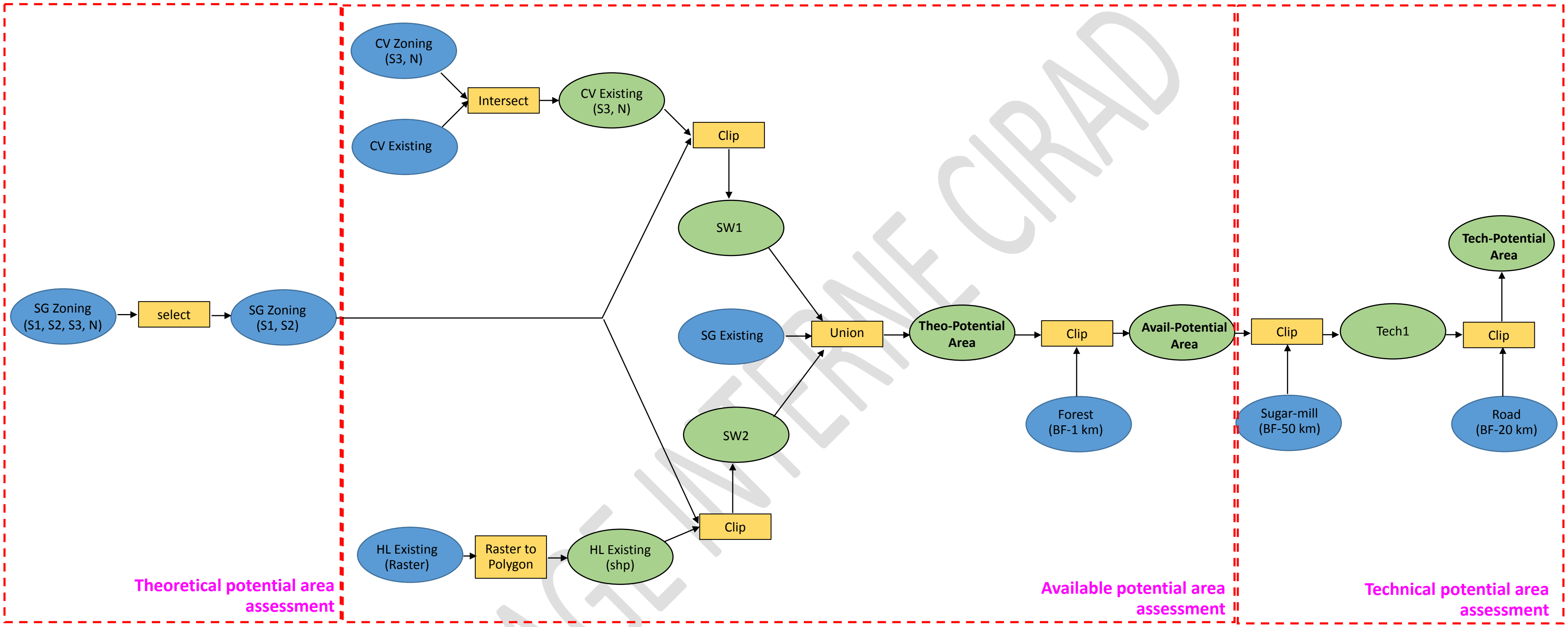
4) The area that is currently used for sugar cane plantation. This constitutes the based-line area of sugar-cane plantation and this area will remain unchanged for as long as farmers do not switch to other crops.
5) The area that has a high potential for switching to sugar cane plantation. This corresponds to the additional area that could be used for sugarcane plantation. Within this, there are 2 sub-groups:
    - The area that is highly (S1) or moderately (S2) suitable for sugarcane and the area that is lowly (S3) or not (N) suitable for cassava but currently used for its production.
    - The area that is highly (S1) or moderately (S2) suitable for sugarcane but currently used for highland rice plantation.
3) The area that can be cultivated with environmental constraints : including, buffer zones around forest areas of at least 1km and buffer areas around rivers of 10m and 50m depending on the size of the river (2 main classes of river are considered)

3.2.3 Technical potential area assessment

The technical potential area is the available potential area in which infrastructural considerations are included, i.e. location of sugar mills and road accessibility. This corresponds to the available potential area located within a 50 km radius of sugar-mill factories and accessible to vehicles via paved-road. Currently, there are 51 sugar-mill factories being operated in Thailand. This defines the maximum potential area for sugarcane production.

3.2.4 Realistic potential area assessment

The realistic potential area is assessed estimating the share of producers that can have an interest to switch from cassava or highland rice to sugarcane. This assessment is made by interviewing farmers and experts, and analyzing sugarcane production systems.



Where:		SW	= Switchable area
SG Zoning	= Area suits for sugarcane growth	Theo-Potential Area	= Theoretical potential area
SG Existing	= Area currently plants sugarcane	Avail-Potential Area	= Available potential area

Figure 3.2 Assessment framework for sugarcane

4. Assessment of suitable areas for bioethanol feedstock production

4.1 Suitable areas for cassava plantations

Based on the methodology described in Chapter 3 to assess the maximum production area of cassava, the results obtained are reported in Table 4.1.

Table 4.1 Assessment results of suitable areas for cassava plantations

	Area (million ha)
Theoretical potential area for cassava	6.800
- Highly and moderately suitable areas (LDD)	6.800
Available potential area for cassava	1.959
- Existing cassava crop	1.916
- Switching from sugarcane to cassava (scenario-based)	0.013
- Switching from highland rice to cassava (scenario-based)	0.192
- Environmental constraints (area switches from sugarcane to cassava)	-0.010
- Environmental constraints (area switches from highland rice to cassava area)	-0.152
Technical potential area for cassava	1.948
- Existing cassava crop	1.916
- Switching from sugarcane to cassava area	0.002
- Switching from highland rice to cassava area	0.030
Realistic potential area for sugarcane	1.934
- Existing sugarcane crop (100%)	1.916
- Switching from sugarcane (100%) and highland rice (53%)	0.018

In Thailand, the theoretical potential area for cassava is 6.8 million ha (as demonstrated in Figure 4.1) including 2.45 million ha for highly suitable area and 4.3 million ha for moderately suitable area. The available potential area for cassava is 1.959 million ha (as demonstrated in Figure 4.2) including 1.916 million ha of land currently used for cassava production (as demonstrated in green color in Figure 4.2.), 0.013 million ha of land with high potential to switch from sugarcane to cassava (as demonstrated in purple color in Figure 4.2), and 0.192 million ha of land with high potential to switch from highland rice to cassava (as demonstrated in red color in Figure 4.2.). However, the available potential excludes 0.162 million ha of land considered as buffer zones (environmental constrain). The technical potential area for cassava is 1.948 million ha or about 99.4% of the available area (as shown in Figure 4.3). The areas related to the available potential and technical potential appear to be quite close; this is because of the spatial distribution of the 337 cassava drier yards and good road network coverage. However, looking at the suitability of highland rice for cassava and sugarcane, it was found that about 47% of that area (or about 0.014 million ha) is suitable for either of the two crops. In that case, the switch is given priority to sugarcane following the current policy of the Thai government in promoting sugarcane production on highland rice. Based on the assumption that 100% of the area of sugarcane identified as suitable for cassava is switched to cassava (0.002 million ha) and 53% of the highland rice area identified as suitable for cassava is switched to cassava (0.016 million ha), it follows that the realistic potential area for cassava is about 1.934 million ha. This includes 1.916 million ha of existing cassava area and 0.032 million ha of additional cassava area (i.e. highland rice and sugarcane). The maximum additional suitable area of land that could be used for cassava plantation is about 0.018 million ha; this is equivalent to about 0.9% of the existing cassava plantation area.

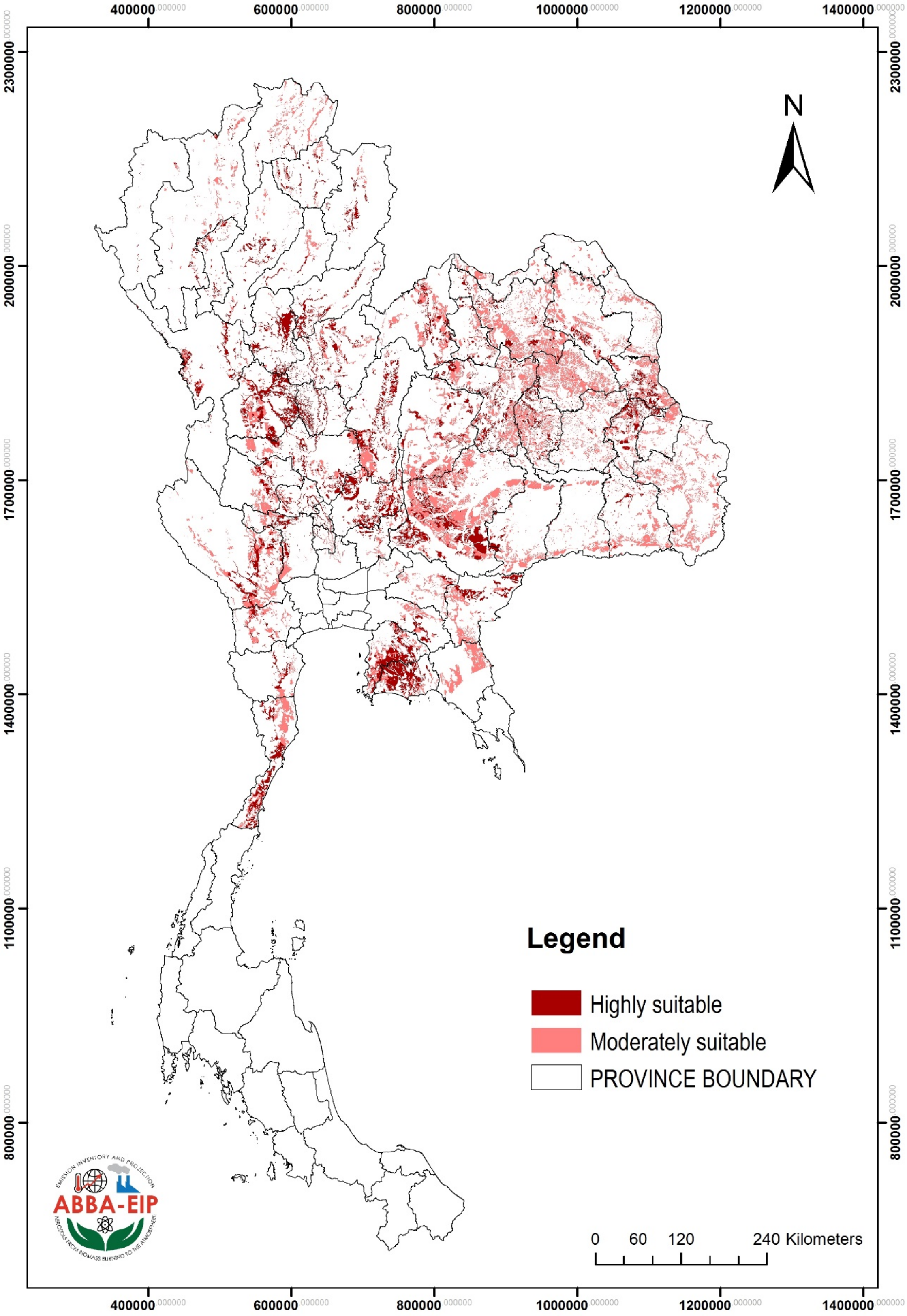
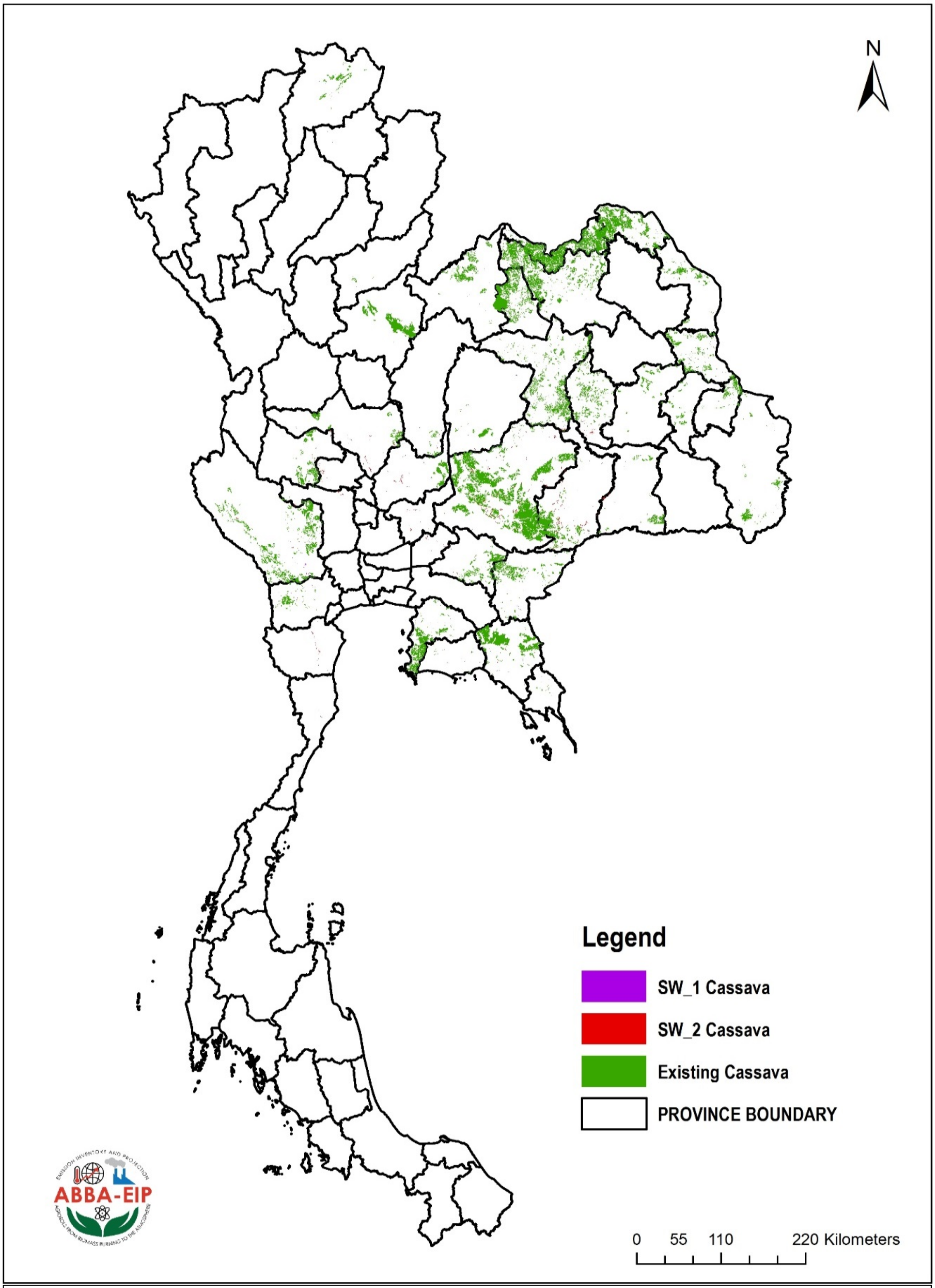
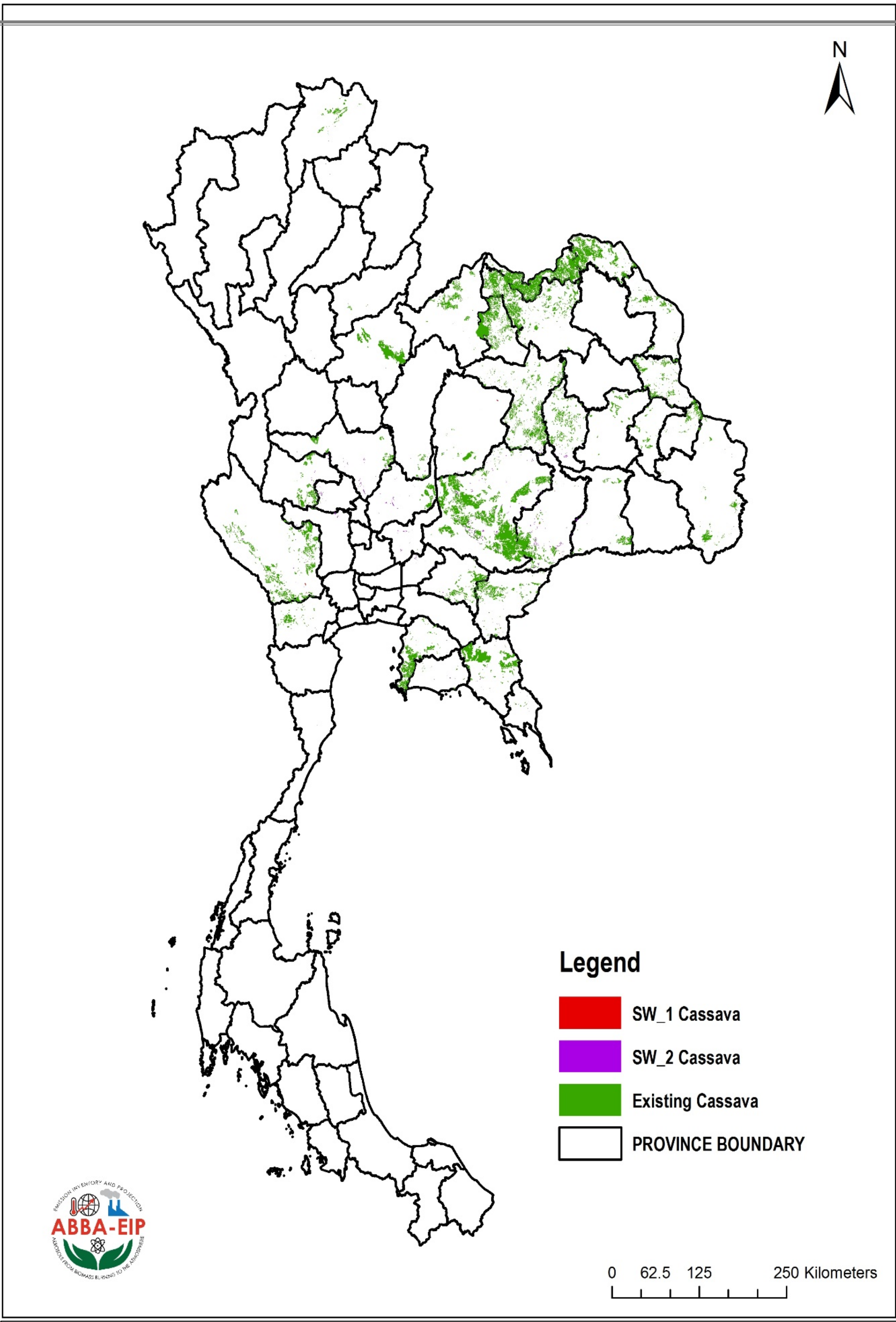


Figure 4.1 Theoretical potential areas for cassava plantations



SW_1 Cassava = Further available potential area of cassava that switched from sugarcane to cassava
SW_2 Cassava = Further available potential area of cassava that switched from highland rice to cassava
Existing Cassava = Existing available potential area of cassava

Figure 4.2 Available potential areas for cassava plantations



SW_1 Cassava = Further available potential area of cassava that switched from sugarcane to cassava
SW_2 Cassava = Further available potential area of cassava that switched from highland rice to cassava
Existing Cassava = Existing available potential area of cassava

Figure 4.3 Technical potential areas for cassava plantations

Models of cassava production:

According to the information collected from the interviews of cassava experts and farmers (information from agronomist experts and farmers are reported in Appendix a and b respectively), there are 3 main stakeholders involved in cassava, i.e. (1) cassava farmers as producers, (2) cassava factories as consumers, and (3) cassava-driers which link cassava producers and consumers. Generally, farmers sell fresh cassava roots to cassava driers. Fresh cassava is then usually processed into cassava dried chips by cassava driers and then sold to cassava factories such as animal-feed factories, cassava starch factories or cassava pellet factories. Cassava driers pay for the product either based on the percent starch content price or as lump-sum price. In many cases, cassava farmers and cassava driers are the same person, especially for large farms. So, there are 2 main production patterns of cassava that should be considered as part of the assessment process of the technical potential area:

a) Cassava-single farm system: this pattern is suitable for a large farm (occupying more than 32 ha) in which the farmer and intermediate can be the same person. In this case, the farmer produces cassava and also processes cassava roots into dried chips prior to selling them to a cassava factory. In this system, there are no contract obligations between the cassava farmer and cassava dryer (in cases where they are different stakeholders) as well as between the cassava dryer and cassava factory. The structure of a cassava-single farm is shown in Figure 4.4.
b) Cassava-cooperate farm: this pattern is suitable for a small farm (occupying less than 8 ha) or medium farm (occupying about 8-32 ha). Many small and medium farmers cooperate to form a group led by a farm leader. The farm leader is responsible for negotiating with cassava-chip driers. The weak point of this pattern is a reliable and dependable person is required as leader of this cooperation system. The relationship between farmers is in the form of member. In this system, there are no contract obligations between the farmer leader and cassava-drier. The structure of a cassava cooperate farm is shown in Figure 4.5

Pattern 1: Single farmer

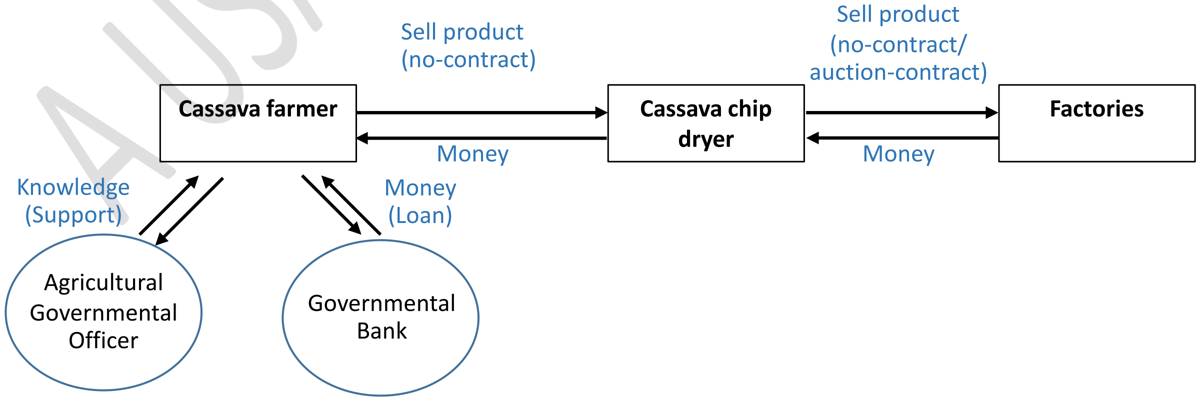


Figure 4.4 Structure of a cassava single farm system

Pattern 2: Cooperation farmers

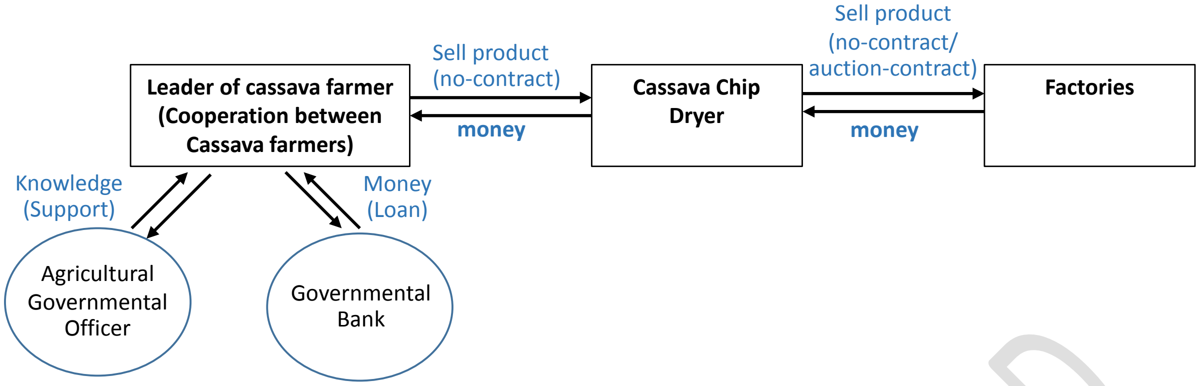


Figure 4.5 Structure of a cassava cooperate farm system

Switching to cassava production - Barriers and opportunities:

According to the information gathered from farmers' interviews, it was found that the switching of sugarcane to cassava plantations is generally caused by the increasing price of cassava and to avoid some issues related to sugarcane disease (farmers break the cycle of sugarcane disease by switching to cassava plantation). Based on farmers' experience, it was reported that high cassava yield could be obtained when switching from sugarcane to cassava plantation. However, to get a high cassava yield, sufficient water availability is also necessary. Agronomist experts suggested that about one-third of the crop plantation area be kept as a water catchment area. In addition, they indicated that to ensure sustainable crop production, a 5 years crop rotation would be recommended, alternating a 4 years production cycle of cassava with a one year of another crop production, for instance legumes. This crop rotation strategy would contribute to enhance soil fertility [12].

It was also found that the switching of sugarcane to cassava is usually not an option of interest. This is because most sugarcane farmers are well established and produce sugarcane over reasonably large plantation areas (over 30 ha). From the survey as well as information gathered from experts, it was found that because of the importance of the sugar industry in Thailand as well as the strong promotion over the last decade of bioethanol in the country, the welfare of sugarcane farmers, especially those with medium to large plantation areas, is of good standard. Sugarcane farmers are usually richer than cassava farmers. The production of sugarcane (cultivation and harvesting) is usually mechanized for farmers with large plantation areas. This investment in machines contributes to encourage farmers continue growing such a crop and not to consider shifting to other crops such as cassava for instance. During the field survey, it was mentioned that even with a lower return than growing cassava, there would be no interest in shifting from sugarcane to another crop unless there would be no demand for it.

4.2 Suitable areas for sugarcane plantations

The assessment of the maximum production area of sugarcane is summarized in Table 4.2

Table 4.2 Assessment results of suitable areas for sugarcane plantations

	Area (million ha)
Theoretical potential area for sugarcane	10.800
- Highly and moderately suitable areas (LDD)	10.800
Available potential area for sugarcane	3.354
- Existing sugarcane crop	1.850
- Switching from cassava to sugarcane (scenario-based)	0.040
- Switching from highland rice to sugarcane (scenario-based)	3.219
- Environmental constraints (area switches from cassava to sugarcane)Environmental constraints (area switches from highland rice to sugarcane area)	-1.73
Technical potential area for sugarcane	2.553
- Existing sugarcane crop	1.850
- Switching from cassava to sugarcane area	0.015
- Switching from highland rice to sugarcane area	0.688
Realistic potential area for sugarcane	2.126
- Existing sugarcane crop (100%)	1.850
- Switching from cassava (100%) and switching from highland rice (38%)	0.276

In Thailand, the theoretical potential area for sugarcane is 10.8 million ha (as demonstrated in Figure 4.6) including 4.4 million ha for highly suitable area and 6.4 million ha for moderately suitable area. The available potential area for sugarcane is 3.3 million ha (as demonstrated in Figure 4.7) including 1.8 million ha of land currently used for sugarcane production (as demonstrated in green color in Figure 4.7.), 0.04 million ha of land with high potential to switch from cassava to sugarcane (as demonstrated in purple color in Figure 4.7), and 3.2 million ha of land with high potential to switch from highland rice to sugarcane (as demonstrated in red color in Figure 4.7.). However, the available potential excludes 1.7 million ha of land considered as buffer zones (environmental constrain). The technical potential area for sugarcane is 2.5 million ha or about 76.1% of the available area (as shown in Figure 4.8) and including 1.8 million ha of existing sugarcane area and 0.7 million ha of switching area.

According to a questionnaire survey from Arunee et al (2013) focusing on farmers producing highland rice in the North East of Thailand and aiming at assessing the proportion of farmers interested or willing to switch from rice to sugarcane, it was estimated that about 38% of the overall paddy field area covered in this survey could be switched to sugarcane [13]. Based on the assumption that 100% of the area of cassava identified as suitable for sugarcane is switched to sugarcane and 38% of the highland rice area identified as suitable for sugarcane is switched to sugarcane as well, it follows that the realistic potential area for sugarcane is only about 2.1 ha. This includes about 1.8 million ha of existing sugarcane area and about 0.3 million ha of additional area (i.e. highland rice and cassava combined); this is equivalent to about 15% of the existing sugarcane plantation area.

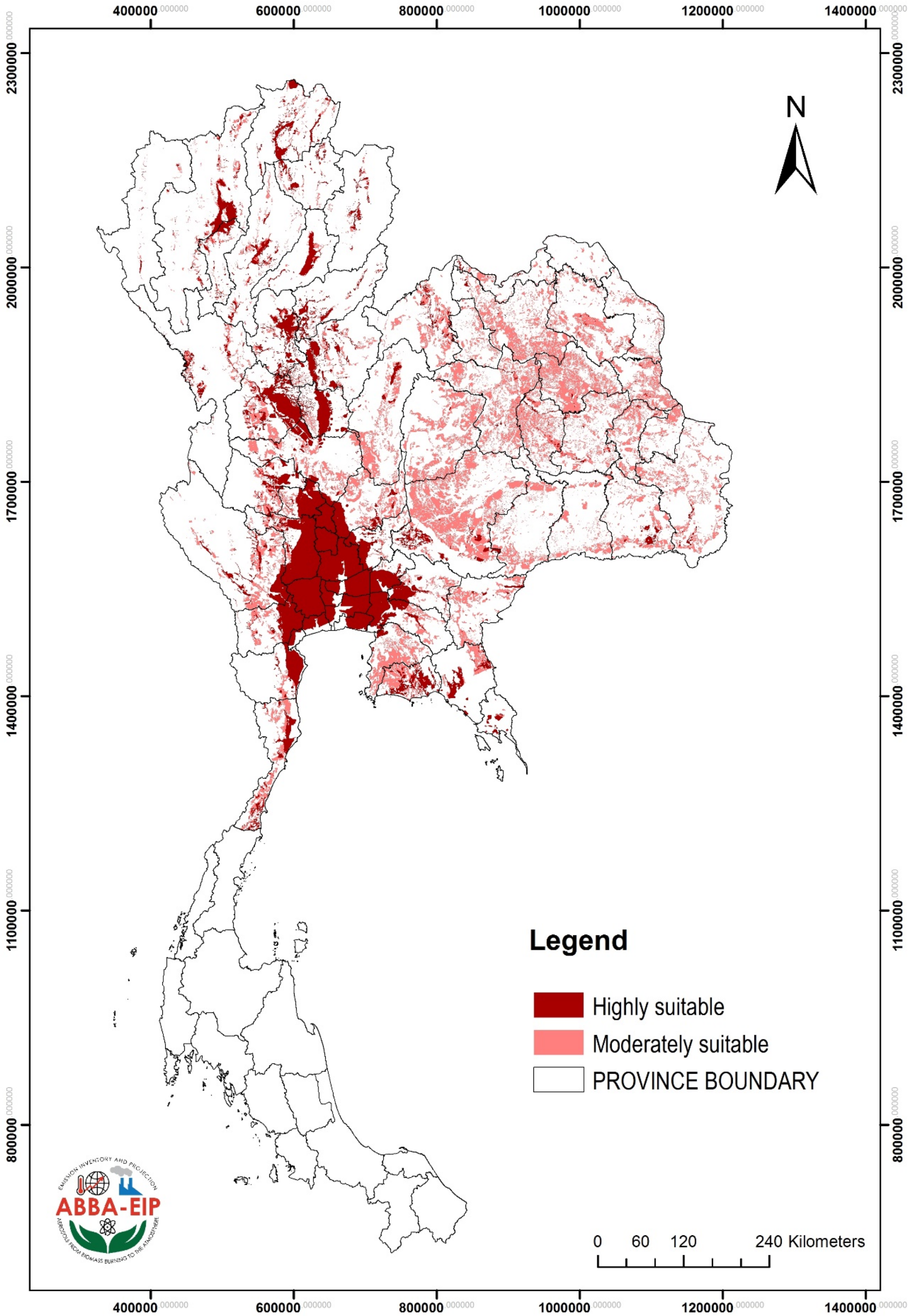
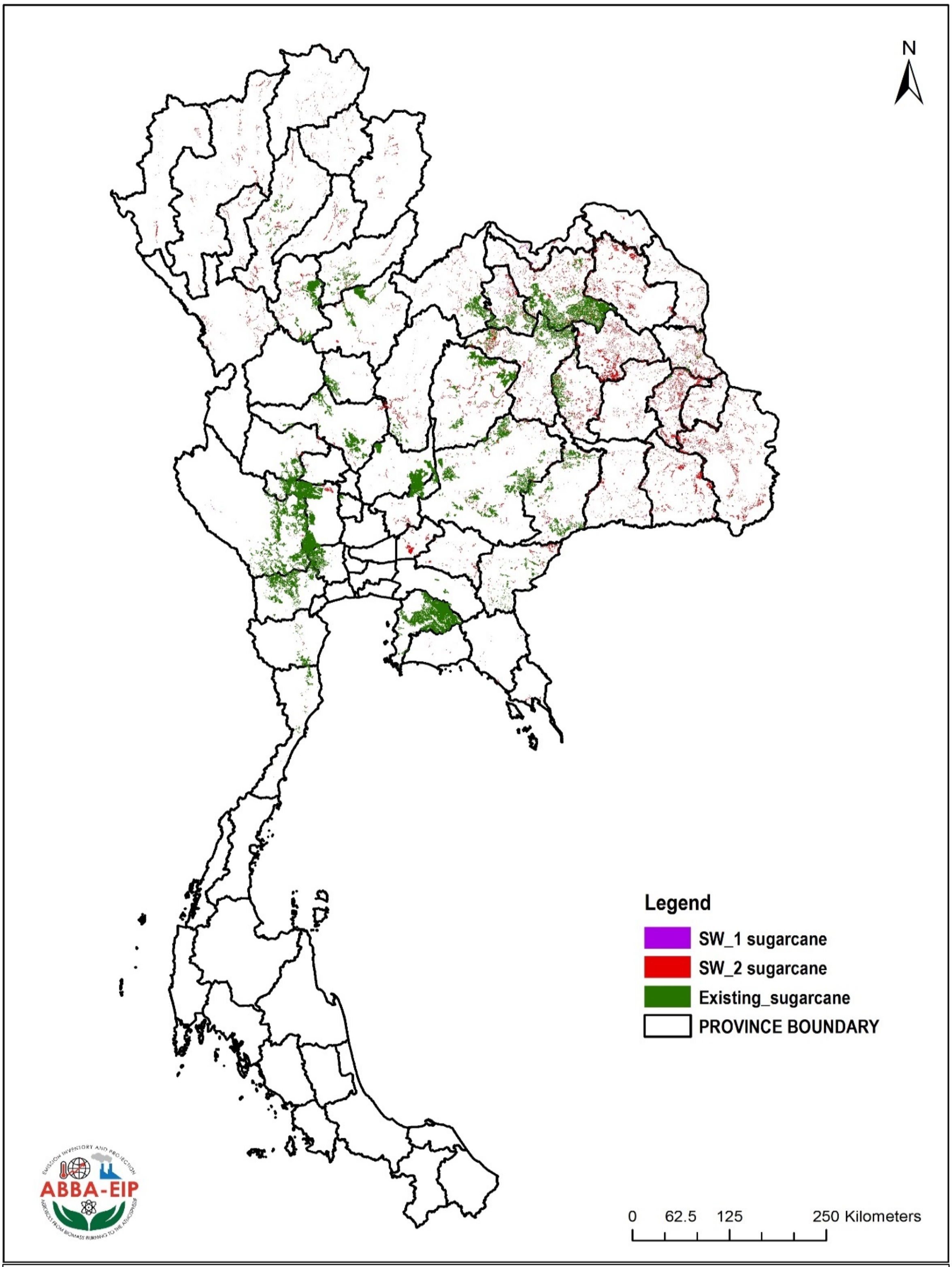
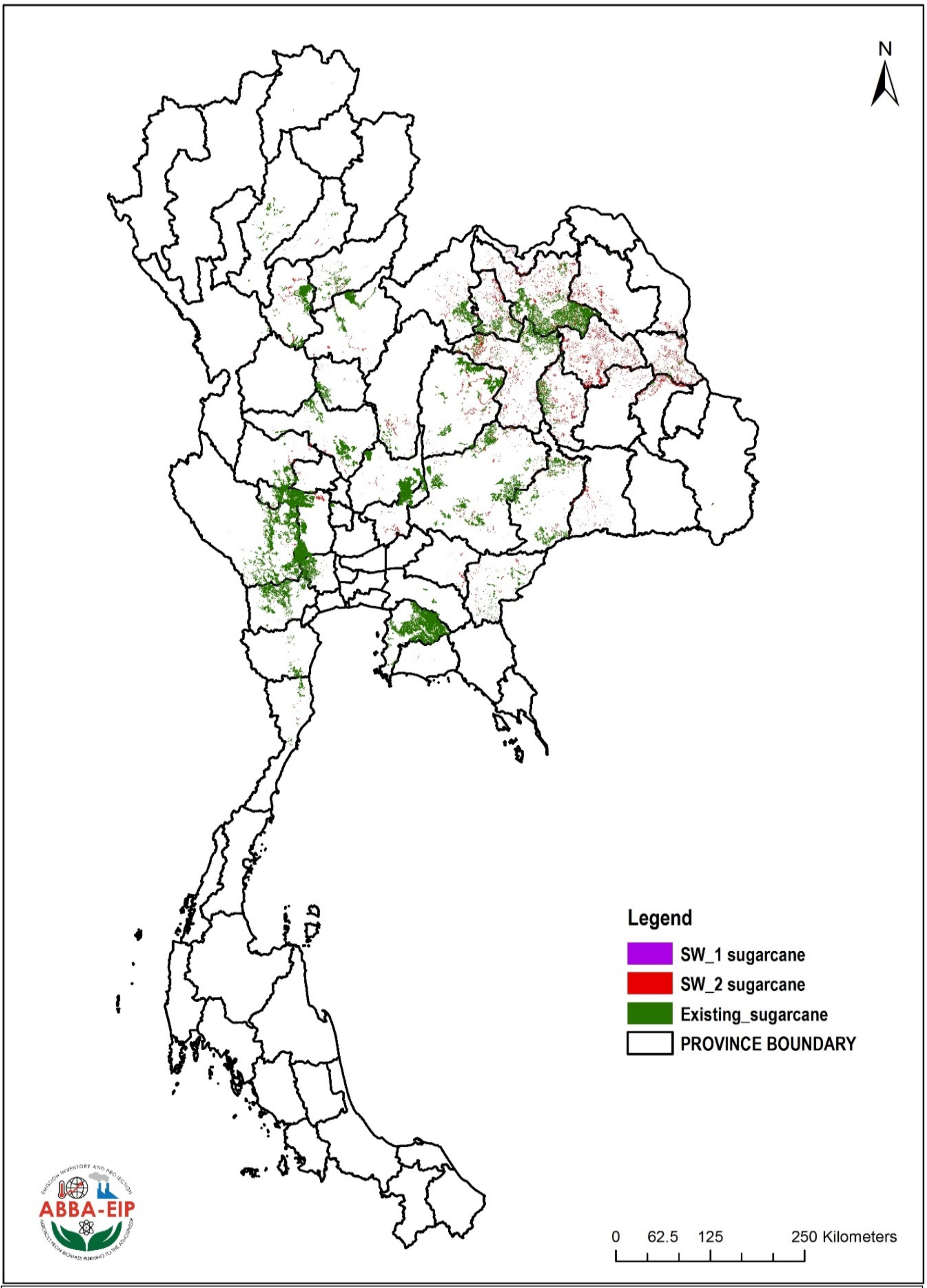


Figure 4.6 Theoretical potential areas for sugarcane plantations



SW_1 Sugarcane = Further available potential of sugarcane that switched from cassava to sugarcane
SW_2 Sugarcane = Further available potential of sugarcane that switched from highland rice to sugarcane
Existing Sugarcane = Existing theoretical potential area of sugarcane

Figure 4.7 Available potential areas for sugarcane plantations



SW_1 Sugarcane = Further available potential of sugarcane that switched from cassava to sugarcane
SW_2 Sugarcane = Further available potential of sugarcane that switched from highland rice to sugarcane
Existing Sugarcane = Existing theoretical potential area of sugarcane

Figure 4.8 Technical potential areas for sugarcane plantations

Models of sugarcane production:

According to the information collected from the interviews of agronomist experts and farmers (information from agronomist experts and farmers are reported in Appendix a and b respectively), it was found that there are 3 main stakeholders involved in sugarcane production, including (1) sugarcane farmers as producers, (2) sugar-mill factories as consumers, and (3) sugarcane quota leaders. Sugarcane quota leaders might be sugarcane farmers or intermediate-agents involved in signing quota-contracts with sugar-mill factories. Generally, a large farm sells its product to a sugar-mill factory while a small or medium farm sells its product to a sugarcane quota leader. The sugar-mill factory provides an advance-credit to the sugarcane quota leader that might request for money or agricultural materials but there is no contract between the sugarcane farmers and the sugarcane quota leader. The price of cane is based on commercial cane sugar (ccs). On the other hand, there is a quota-based contract arrangement between the sugarcane leader and the sugar-mill factory to which the product is supplied. The structure of the sugarcane system is shown in Figure 4.9.

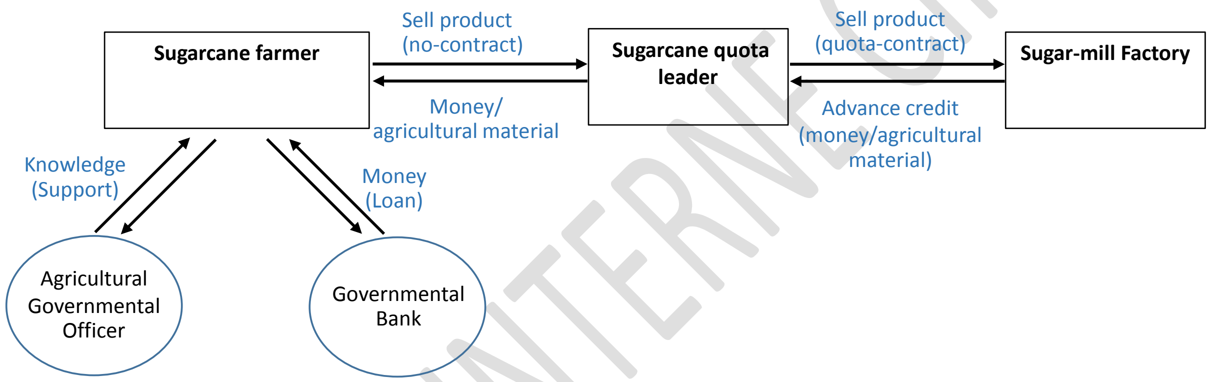


Figure 4.9 Structure of a sugarcane farm system

Switching to sugarcane production - Barriers and opportunities:

The switching of cassava to sugarcane was found to be contributed/influenced by an increase in the price of sugarcane. According to a report from the office of the cane and sugar board, it was observed that during the crop season 2013/2014 the sugarcane area had increased as a result of an increase in the price of sugar as well as suitable weather conditions for sugarcane production. The increase in the area of sugarcane is mainly due to a shifting from cassava or maize or rice [14].

In case of switching from highland rice to sugarcane, based on the study from Arunee et al (2013), it was found that the reasons for farmers to make the switch include: getting a higher income (the income from sugarcane plantation is about 3.6 times that of the income from rice plantation), having a lower drought risk, and the influence from other successful farmers. The reasons for farmers not be interested in making the switch included: having a small area of plantation (less than 1.6 ha), requiring a higher investment cost to make the switch, and having to produce rice to satisfy own consumption. In any case, major factors that should be considered to produce sugarcane in highland areas include: topography of the land (accessibility to machines), suitability of sugarcane variety (should use a drought resistant variety), the demand and the capacity of the sugar-mill factories, and timing of sugar-crushing.

5. Conclusions and Recommendations for Future Studies

5.1 Main findings

This study aimed at assessing the maximum suitable areas that could be used for cassava and sugarcane plantations in Thailand. This was done following an assessment framework adapted to the context of Thailand and based on a methodology initially developed by CIRAD. A suitable land area is one that provides the soil conditions and water availability adequate for cassava and sugarcane cultivation and which current land use can be switched to either crop (theoretical potential), it is land area that takes into account buffer zones (available potential), and finally it is land that is accessible via paved road and located within adequate distances from cassava and sugarcane factories (technical potential).

Thailand has a geography and topography that supports the production of cassava and sugarcane. The total area of the country is 51.31 million ha. About 46.5% of the country's total surface is used for agricultural activities. About 8.2% (1.96 million ha) is occupied by cassava plantations and 7.7% (1.85 million ha) by sugarcane plantations. Looking into the details of the land available for agricultural production, it has been found that there is already a saturation of that land in Thailand. Hence the land potential for expansion of sugarcane and cassava plantation is limited. Highland rice is the only potential alternative land that could be considered for expansion of existing cassava and sugarcane plantations.

Based on criteria of soil suitability and water availability from the Land Development Department (LDD) of Thailand, it has been found that 6.8 and 10.8 million ha of land in Thailand fulfills the requirements for cassava and sugarcane production respectively.

Suitable areas for expansion of cassava plantations

- Taking into considerations the existing total area of cassava plantation in Thailand, i.e. 1.916 million ha, and including land suitability criteria from LDD as part of the assessment framework followed in this study, it was found that about 0.013 million ha of sugarcane and 0.192 million ha of highland rice could be switched to cassava. Adding environmental constrains (buffer zones) and infrastructure considerations as part of this assessment, the overall land area for cassava production was determined to amount to 1.948 million ha (technical potential).
- Based on the previous assessment, and including social and policy considerations, it was determined that about 0.018 million ha of additional land (sugarcane and highland rice) can actually be used for cassava expansion, bringing its realistic potential area to 1.934 million ha.

The suitable areas for expansion of sugarcane plantations

- Taking into considerations the existing total area of sugarcane plantation in Thailand, i.e. 1.850 million ha, and including land suitability criteria from LDD as part of the assessment framework followed in this study, it was found that about 0.040 million ha of cassava and 3.219 million ha of highland rice could be switched to sugarcane. Adding environmental constrains (buffer zones) and infrastructure considerations as part of this assessment, the overall land area for sugarcane production was determined to amount to 2.553 million ha (technical potential).

- Based on the previous assessment, and including social and policy considerations, it was determined that about 0.276 million ha of additional land (cassava and highland rice) can be used for sugarcane expansion bringing its realistic potential area to 2.126 million ha.

The above results indicate that the expansion of cassava and sugarcane plantations in Thailand is quite limited. For cassava, the additional area that could be switched to cassava equates only about 0.9% of the existing cassava plantation. For sugarcane, the potential is larger, with an additional potential area equivalent to about 15% of the existing sugarcane plantation. The expansion in either case is essentially contributed by highland rice; switching from cassava and sugarcane plays a minor role in either scenario.

5.2 Recommendations for future work

A limitation of this study concerns the field surveys that were performed as they involved a restricted number of farmers. A more detailed study on cassava and sugarcane with larger samples should be performed in order to obtain more detailed and representative information regarding cassava and sugarcane farmers in Thailand as well as cassava and sugarcane processors. This would enable to refine the information related to the production systems of cassava and sugarcane and so of the corresponding production scenarios considered for Thailand. Also, additional information concerning the topography of the land identified as highland rice should be collected to ensure that the slope is adequate for the production of either cassava or sugarcane.

There are a number of other crops and biomass based materials of potential for bioenergy in Thailand. Additional works related for instance to the potential of ligno-cellulosic materials, e.g. agricultural residues, could be investigated based on the methodology followed in this study.

The investigations performed in this study for Thailand could be extended to ASEAN. With regard to bioethanol, mainly ASEAN countries including Thailand, Cambodia, Lao PDR, Myanmar, and Vietnam are concerned. The methodology might start from the satellite information and other secondary data at global scale to define the theoretical potential area, available potential area, and possibly the technical potential in these countries.

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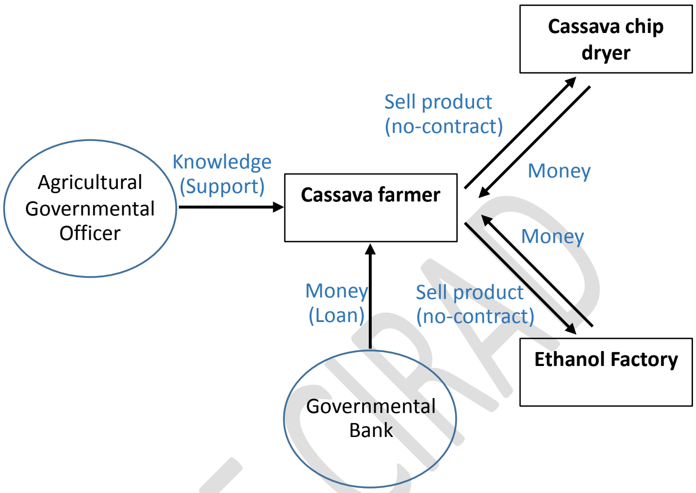
Appendix a: Information from farmer interview

1) Cassava farmer 1 (Chainat province)



Farming characteristic:

- Household business + 4 workers
- Total plantation area 12.8 ha and 10,000 heads of chicken
- Uses compost-fertilizer 3.125 ton/ha (chicken manure (from the farm) + cassava peal (bought from the cassava chip dryer))
- Uses tube-water system
- Gets yield 50 tons/ha with 27%-29% of starch (higher than the average yield of Chainat province @ 25 tons/ha)
- Loans money from governmental bank
- Never shift crop because the area is only suitable for cassava plantation

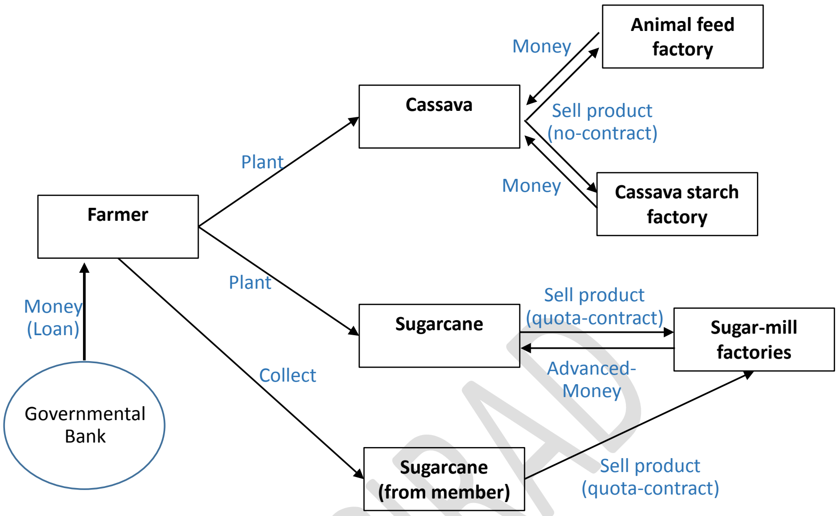
Supply chain characteristic:

- No contract farming (no obligation, freedom to select the partner)
- Partner: cassava chip dryer and ethanol factory depend on % starch of crop
  if the product > 25% starch ethanol factory @ 3,000 baht /ton
  if the product < 25% starch 1) cassava chip dryer with % starch based price
  2) cassava chip dryer with lump sum price
    - Farmer sends the product to partner (30-60 km distance) by truck.

Suggestion/Opinion:

- Farmer will get the higher power and profit by doing the cooperation between farmer
- Farmer should always find the more knowledge by attending the cassava plantation practice program.
- The threat, price decreased because of cassava from Cambodia

Cassava and sugarcane farmer 2 (Chainat province)



Farming characteristic:

- Household business + workers
- Total area 19-24 ha, about 6.4 ha used for cassava plantation and the rest area for sugarcane plantation
- Gets cassava-yield 18.75 tons/ha; sugarcane-yield 50-62.5 tons/ha with the natural plantation method
- Starts to use the water system for sugarcane, about 25,000-31,250 baht/ha for the cost of water system
- Farmer decides to shift the crop because the crop-disease and crop-price changing, (the next crop has to switch 3.2 ha of sugarcane to cassava because of sugarcane-white leaf disease)
- Sugarcane is harvested by human worker and burns before harvesting

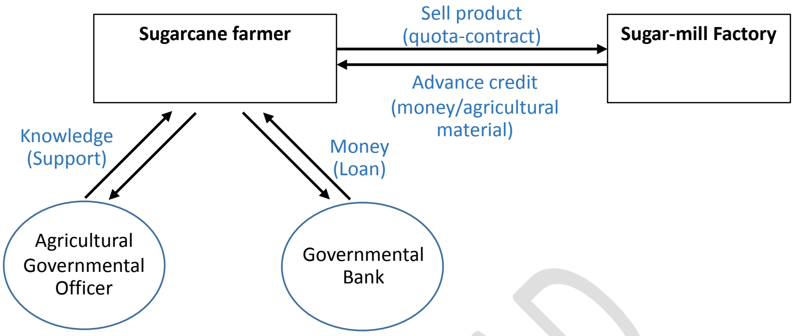
Supply chain characteristic:

- This farmer is also a cassava-chip drier, the high quality product is sold to the animal feed factory and low quality product is sold to the cassava-starch factory.
- Farmer sends the cassava dried chip to factory by tractor with the capacity 20 tons/trip
- Farmer sends the cane to sugar-mill factory (30 km distance) by truck-trailer with the capacity 40-50 tons/trailer.
- Farmer gets total 4,000 tons quota from 2 sugarcane-mill factories (2,000 tons for each), he need to find the sugarcane farmer member (mostly cousin) to reach the quota. The contract with sugar-mill factory was done year by year.

Suggestion/Opinion:

- Farmer wishes the government to launch the law for controlling the maximum of the land tenure (to protect the small farmer)
- Farmer wishes the government to support the graduated student to be a farmer

Sugarcane farmer 3 (Petchaboon province)



Farming characteristic:

- Household business + workers (hiring about 15 workers only for harvesting).
- Total area 40 ha, 32 ha is used for sugarcane (about 19.2 ha uses water tube system and 12.8 ha uses natural plantation method), 4.8 ha is used for maize, and 3.2 ha is used for paddy
- Farmer plants maize because the area suits only for maize plantation.
- The sugarcane product is sold to sugar-mill; maize product is sold to animal-feed factory; rice is used in the family (not for sale).
- Yield in water-tube system area about 112.5-125 tons/ha for first-ratoon and about 81.25-93.75 tons/ha for second-ratoon; Yield in natural plantation area about 50-62.5 tons/ha for first-ratoon and about 43.75-62.5 tons/ha for second-ratoon.
- Use chemical-fertilizer 625 kg/ha and compost-fertilizer (chicken manure) 250 kg/ha
- Sugarcane is harvested by human worker.

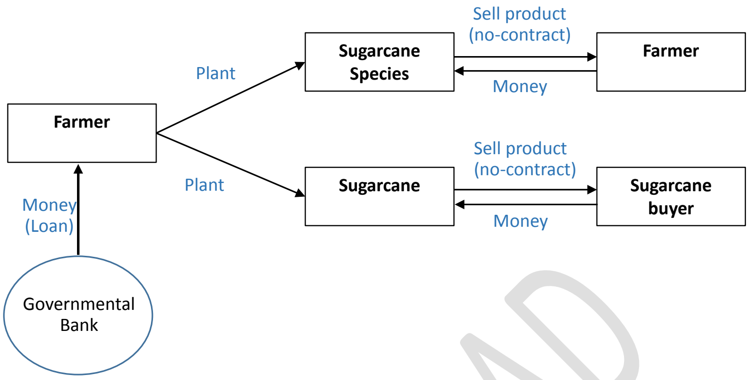
Supply chain characteristic:

- Farmer gets quota from sugar-mill factory about total 2,500 tons.
- Farmer sends the sugarcane to sugar-mill factory (20 km distance) by tractor with the capacity 30-40 tons/trip (using diesel 25 litre/trip)
- Farmer gets the advance-money from sugar-mill factory and also loans money from the governmental bank (Farmer prefers to loan money from governmental bank than advance-money from sugar-mill factory because of lower interest)

Suggestion/Opinion:

- 18 years ago, all of plantation area was used for rice cultivation, then shifted to sugarcane plantation because of the increasing of sugarcane price.
- The reasons that farmer decides to shift the crop (from sugarcane to rice, sugarcane to maize) are the crop-disease problem and the low yield (if the yield lower than 43.75 tons/ha).
- From his experience, the crop rotation enhances the yield.
- The way of sustainable production is to limit the plantation area according to the own ability and also crop-rotation.

Sugarcane farmer 4 (Loei province)



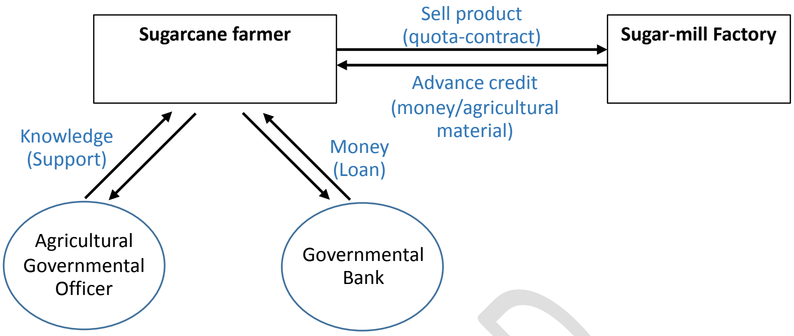
Farming characteristic:

- Household business
- Total area 4.8-8 ha, 0.64 ha used for sugarcane-specie, and the rest used for cane.
- Sugarcane is harvested by human worker.

Supply chain characteristic:

- Farmer sells the sugarcane-species to farmer with the price 1,000 baht/ton (exclude the harvesting and transport cost) and sells the sugarcane to the buyer with the weight price.

Sugarcane farmer 5 (Loei province)



Farming characteristic:

- Household business + 2 permanent workers + 10-20 temporary workers (only harvesting season)
- Total area 48 ha for sugarcane cultivation, 11.2 ha for para-rubber, 1.6 ha for paddy, 60-70 heads of chicken, 40 heads of duck
- Average sugarcane-yield 62.5-93.75 tons/ha
- Sugarcane is harvested by human worker.

Supply chain characteristic:

- Farmer gets quota from sugar-mill factory about total 3,000 tons.
- About 50% of funding obtained from advance-money of sugar-mill factory and 50% obtained from the governmental bank. (Farmer prefers to loan money from governmental bank than advance-money from sugar-mill factory)

Cassava chip dryer 1 (Chainat province)

- Family business plus 2 permanent workers
- Buy the cassava from the general farmer (frequenter with no contract), the farmer transport the cassava to the cassava chip dryer
- During the dry season, need to find the product within 50 km radius
- The price of cassava upon % starch and cleaning of the product, farmer will get the add-up money if the product has the higher % starch and cleaning
- The high quality cassava will sell to animal feed mill. (animal feed mill provide the high price but require the limit quantity) by tractor with the capacity 20 tons/trip (dried chip)
- The maximum distance between plant to factory is about 300 km
- No cooperation between cassava chip dryer

Suggestion/Opinion:

- To do cassava chip dryer, it need area at least 4.8-8 ha and storehouse

Cassava chip dryer 2 (Chainat province)

- Cassava chip dryer + cassava plantation area (more than 160 ha). The area was shifted from eucalyptus to cassava because of the lack of the cassava product.
- The area is rent by the farmer and the farmer has to sell the product to the cassava chip dryer.
- Buy daily average 500 tons (200 tons/day in the dried season), maximum 1,000 tons/day (Jan-Feb)
- Support money and chemical-fertilizer to the farmer
- 2 main partners: animal feed mill (15-20%) and export factory (80%)
- Export factory is mostly sent to China (China uses cassava to produce low quality of drinking alcohol)
- Animal feed mill provides about 0.4-0.5 baht/kg higher price than export factory
- Maximum distance 150 km between cassava chip dryer and factory
- To storage the productivity, it need to decrease the moisture content of the product to 14%

- This cassava chip dryer join the project of department of industry to get the certificate of the cleaning of factory.

Suggestion/Opinion:

- He is willing to do the contract farming between the cassava chip dryer and factory but not willing to do the contract farming between cassava chip dryer and farmer because he would like to select the product as his requirement
- The optimum price of cassava should be 2.30 baht/kg (in the perspective of trader)
- Government should have the clear policy, government always provide incomplete information

Sugarcane-mill factory (Phu-luang, Loei province)

- This factory has operated since 3 year 2012 with the total crushing capacity 21,000 tons/day, crushed 2.58 million tons of cane (year 2015). The amount of crushing has continuously increased.
- The factory has a target to increase the crushing capacity according to the increasing of sugarcane area.
- The factory obtains the cane from about 5,000 farmers within the 50 km radius with the total sugarcane cultivation area 32,500 ha.
- The policy of the factory is to transfer knowledge of cane-farm to farmer and to support the cane management efficiency for farmer (focusing on high yield).
- Some of bagasse is used as a fuel in the factory and some is sent to the affiliate factory.
- This factory also has the ethanol business with located in Kalasin province. The feedstock (molasses and sugar juice) for ethanol obtained from the sugar-mill factory in Phu-viang branch and Phu-luang branch.

Appendix b: Information from agronomist expert interview

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<u>Comment of expert 1</u>: crop price (first priority), where to sell the crop/ possible to find the labor for harvesting). Farmer does not care much about their plantation knowledge.

Comment of expert 2: crop price

2. Appropriate area for expansion of cassava and sugarcane plantation (Is it realistic to replace field crop area/ perennial crop area/ orchard crop area/ horticultural crop area with cassava or sugarcane plantation?)

<u>Comment of expert 1</u>: Cassava and sugarcane are in the grouped of the field crop (as pineapple, maize, bean, etc.). From his experience, he has seen only the switching between crops that in the grouped of the field crop only. The farmer always changing the crop plantation whenever the price of that crop is increased. For example, currently, the price of cassava is about 2.7 baht per kilogram (which higher than the previous year), farmer changes from pineapple plantation to cassava plantation. He has never seen the switching across the crop grouped as perennial crop/ orchard crop/ horticultural crop

Comment of expert 2:

- They always have seen the shifting from pineapple plantation to cassava or sugarcane plantation and shifting between cassava and sugarcane plantation.

3. Constrains/conditions to be considered for cassava/sugarcane plantation for ethanol production

Comment of expert 1:

- To get the high cassava yield, the plantation area should has enough water (at least one-third of the plantation area) and also the good land preparation before plantation.
- The distance between the plantation area and the trading center is about 50 kilometer

Comment of expert 2:

- In Thailand, the distance between sugar-mill factories must at least 80 km. (based on the Sugar Act)
- Should take consideration on the demand and the price of the product

- Should change the law related on the using of sugar-juice for ethanol production. Currently, Thailand has only one ethanol-factory which produce ethanol from sugar-juice

4. Model of sustainable production of energy crop for ethanol production

Comment of expert 1:

- Under the responsibility and goal of the center of agricultural engineering technology promotion, they support to increase the crop yield rather than increasing of the planting area.

Comment of expert 2:

- Should consideration on the suitable ranking level (highly/ moderately/ lowly) of the existing area of cassava/sugarcane plantation firstly, then develop the scenario that appropriate for each suitable ranking level. For example, in the lowly suitability of cassava plantation area may require the higher investment cost to get the same amount of production as in the highly suitability area.

- The stakeholder of sugarcane plantation:

(1) sugarcane farmer takes a responsibility on the planter (small-farm: less than 50 rais/ medium farm: 50-200 rais/ large-farm: more than 200 rais)
(2) government (ministry of agriculture and cooperative/ ministry of commerce/ ministry of industry) takes a responsibility on governance
(3) sugarcane association/ sugar mill association (supporting stakeholder)

- Under the responsibility of the field crop research institute, they support to increase the crop yield rather than increasing of the planting area.

5. Business pattern of selling cassava/sugarcane product

Comment of expert 1:

- The middle-sellers (mostly a big-farm) got the quota from the sugar-mill factory, then they collect the sugarcane-product from the farmer- member. The farmer-member receive the money from the middle-sellers directly.
- The sugar-mill factory has a crop department (takes a responsibility on finding the raw material (sugarcane) for example where/how much) and a support department (takes a responsibility on the invite/encourage the farmer to plant sugarcane (sign contract-farming with a farmer)