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***Satoyama* System Establishment as Sustainable Land Management
in Sabah, Malaysia**

(マレーシアサバ州における

持続的な土地管理としての里山システムの構築)

**Hokkaido University Graduate School of Agriculture
Division of Bio-systems Sustainability Doctor Course**

Kazunobu Suzuki

Declaration

I hereby declare that;

- i. this thesis only contains my own original work, and
- ii. all other material used has been duly acknowledged in the text.

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Chapter 1 Introduction

1.1 Current issues and general challenges

The twentieth century brought about enormous economic expansion and social change in many nations in the world. Expansion of trade across nations raised the productivity and competitiveness globally. Particularly in Asia, which experienced widespread economic stagnation during the 1950s, rapid economic growth occurred in the latter part of the twentieth century as the trade system spread across countries such as Japan, South Korea and China, and throughout Southeast Asia. However, these incredible economic developments placed a substantial burden on the environment. Most developed countries experienced excessive pollution during rapid economic growth. Current socio-economic systems are characterized by mass production, mass consumption and mass disposal (Uwasu, 2011). As globalization promotes productivity and competitiveness in the agricultural sector, a petroleum-based society is also promoted. As a result, energy resource management became a critical issue. At the same time, the usage of chemical fertilizers has been on the rise in order to increase agricultural productivity to meet the demand of the global market, and land for agriculture has been expanded by mono-culture types of agriculture. Commercial organic markets which used huge amounts of energy, destroyed local production as well (Gliessman, 2006). Food security and land use management have also become an issue to be carefully considered.

As environmental degradation resulting from farming is becoming a serious problem on both the local and global scales, many conventional farmers are choosing to

make the transition to practices that are more environmentally sound and could potentially contribute to long-term sustainability of agriculture. Sustainable agriculture would ideally produce good crop yields with reduced negative impacts on ecological factors such as soil fertility and utilize minimal inputs for production (Pimentel *et al.*, 1997). Farming practices for sustainable land management through sustainable agriculture which promotes coexistence between humans and nature should focus on replacing the chemicals used in farming but also on redesigning the agro-ecosystem to maximize the ecological, economic and social synergies among them and minimize the conflicts (Komatsuzaki, 2011).

1.2 Current issues and challenges in the context of land management in Sabah

In Sabah, around 21 % of the total land surface area is designated as totally protected area within which human activities are strictly regulated (Annual Report 2014, Sabah Forestry Department). A large scale plantain industry has been put in place and population growth has been a threat for natural and land resources in Sabah. The current dwindling state land resources which are still available for alienation for agricultural development also underline the urgent necessity to utilize these resources wisely and in the most optimum and sustainable basis, so as to maximize their productivity and income generating potential, for the economic benefits of the state. Efforts to develop efficient marketing systems and strategies to ensure competitiveness in both local and foreign markets are also given greater attention (Second Sabah Agricultural Policy 1999-2010).

In the meantime, there are numerous reports globally of conflicts between management authorities and local communities around the borders of and within protected areas in the context of land use and natural resource use (JICA SDBEC, 2014). Conservation and protection of indigenous biodiversity and promoting environmentally friendly practices to minimize the negative impact of agricultural development on the environment are given emphasis.

Considering above, it can be said how to manage limited land with a concept of coexistence between humans and nature is a big challenge in Sabah. In this light, *Satoyama* system might be a good model as sustainable land management system to be introduced in Sabah.

1.3 The concept of ‘*Satoyama*’ and the ‘*Satoyama*’ System

‘*Satoyama*’ is a Japanese Term and another way of expressing ‘farm forest’ (Mori, 2001), and ‘*Satoyama*’ represents a buffer area between the ‘Sato’ (society or [society-humans]) and ‘Yama’ (nature) (Iinuma, 2010). The ‘*SATOYAMA*’ used in the ‘the International Partnership for the Satoyama Initiative (IPSI)’ of the United Nations Educational, Scientific and Cultural Organization (UNESCO), however, stands for ‘Socio-ecological production landscapes and seascapes (SEPLS)’. The term ‘*Satoyama*’ has its historical roots in rural Japanese society. However, it is Tsunahide Shidei (1911-2009), a forestry ecologist, who conducted research focusing on material circulation (production, consumption and decomposition of organic matter), who defined ‘*Satoyama*’ as a ‘farm forest’ from which we obtain the fertilizers required for farmland fertility. Since then, the term ‘*Satoyama*’ has come to be used to express such

a ‘farm forest’ concept. ‘*Satoyama*’ generally represents landscapes that comprise a mosaic of different ecosystems including forests, agricultural lands, grassland irrigation ponds and human settlements aimed at promoting viable human nature interaction (Duraiappah and Nakamura, 2012). In a nature-human-society framework the main components are society (Sato) and nature (Yama), and a framework where humans are closely involved in both of the other components, and this is defined as the *Satoyama* System. *Satoyama* is a system of nature-human co-existing, having a material (nutrient) cycle and nature capital conversation. Therefore, *Satoyama* concept is different from protection of nature (Osaki, 2014). And from the initial discussions about *Satoyama* there is no unified definition used to describe such landscapes, but since the IPSI was established during the 10th Conference of the Parties to the Convention on Biological Diversity (CBD COP10) in Nagoya, Japan in 2010, the term “Socio-Ecological Production Landscapes and Seascapes (SEPLS) has been widely recognized and used worldwide. SEPLS has been focusing on more human interaction with nature for realizing human-nature coexistence or a society in harmony with nature.

A society in harmony with nature is a concept that integrates society, nature (ecology and environment) and people (humans) as they are related to each other and interpreted as a causal factor. Considering this, it becomes possible to see the nature-human coexistence society as presenting an unstable problem comprising a nature – people – society framework that may be solved by developing an arrangement that stabilizes such relationship. In this connection, in a nature – people – society framework, the main components are society (Sato) and nature (Yama), and a framework where humans are closely involved in both components, and this is defined as the *Satoyama* System. However, the natural conditions on which the self-supporting

sympiotic system of this social (Sato)-nature (Yama) can be maintained for long periods of time (thousands of years) are subject to clear restrictions. Because natural (undisturbed) conditions that maintain this independently coexistent system of society (Sato) and nature (Yama) are very restricted, it would be appropriate to think of the sustainable *Satoyama* System as largely limited to parts of East, Southeast, and South Asia (Osaki, 2014).

The ‘*Satoyama*’ refers to the ‘*Satoyama* System’, which expresses a stratification to use the universally available low intensity solar energy effectively based on the idea of a society with nature-human coexistence (Osaki, 2014). A representative example of the ‘*Satoyama* System’ discussed in this thesis exists in the ‘Asian Crescent’ proposed by Osaki (Osaki, 2014), comprising the stratification and complex three-dimensional structure and including different levels of the ‘*Satoyama* System’ from limited regions to the whole of the geographical area (the extremely wide area encompassing the Himalaya-Plateau of Tibet, Borneo, the Japanese archipelago).

A sustainable *Satoyama* system has remained unrealized due to the rapid increase in availability of fossil fuels from the 19th century, and presently a deterioration of the global ecology and environmental conditions have become strikingly obvious in conjunction with the failures and denial of opportunities for it to develop. The nature-human coexistence is well known as *Satoyama* (system) in Japan, and such a system has been recognized in South Asia for generations. *Satoyama* system is a small and economically ineffective system in terms of modern agricultural productivity, thus can be innovated and often is transformed into large scale plantation industries. However, such large scale industries are mainly sustained by fossil fuels and non-renewable energy. It is clear that such a system cannot be sustained due to resource

depletion and waste disposal problems (Osaki, 2014).

Nowadays, our society is facing with multiple sustainability challenges such as population growth, resource limitation including food and energy resources, and environmental deterioration. As a response, in the world a variety of efforts have been undertaken and some new and appropriate technologies and measures have been developed. Among them is *Satoyama* system which is based on the concept of human-nature-society inter-related system which promises to cope with such challenges.

1.4 The research objective and question

This thesis is aimed at demonstrating the *Satoyama* system establishment as suitable for achieving sustainable land management in Sabah, Malaysia by estimating and evaluating food self-sufficiency, biomass energy potential, and social and natural capital. Two research questions were set, namely ‘What are the indispensable components to establish the ‘*Satoyama*’ system?’ and ‘How the ‘*Satoyama*’ system can be maintained and strengthened? ’ By answering these questions, this thesis visualizes some important components for establishing the *Satoyama* system which were analyzed by using information and data through a case study in Sabah State, Malaysia. And this thesis provides a cue or guiding basis for discussing future perspectives to realize the *Satoyama* system.

1.5 Overview

Chapter 2 explains the material used by this research and methodology employed including data collection and data analysis in the research. Study area descriptions include the current status of biodiversity, and living conditions in Sabah, Malaysia as well as Tudan village which was selected as a case research site.

Chapter 3 shows the results of the research. These includes the evaluation of biomass energy potential in Sabah (Session 3.1), evaluation of energy based food self-sufficiency potential in Sabah (Session 3.2), analysis of energy consumption and biomass energy potential at Tudan village (Session 3.3), Analysis of Social Capital (Happiness degree) at Tudan village (Session 3.4) and Analysis of Natural Capital at Tudan village (Session 3.5). Each session explains introduction, result, discussion and conclusion.

Chapter 4 is a general discussion on the basis of the results presented in the Chapter 3 and discusses the current challenges and future perspectives including future possible actions in the context of *Satoyama* system for realizing a sustainable society in Sabah. In addition, this chapter identifies the issues and ideas which can be replicated to others in Sabah and Malaysia as a whole, or even internationally.

Finally, **Chapter 5** summarizes all the main findings and offers a perspective on the way forward.

Chapter 2 Material and Methods

Session 2.1 Study areas description

2.1.1 Situation of Sabah State, Malaysia

2.1.1.1 Sabah in brief

Sabah is located in the northern part of Borneo Island with its landscapes and seascapes ranging from the highest peak in the Malay Archipelago (Mount Kinabalu) to lowland tropical rainforest and winding rivers that flow into beautiful coral reefs. Sabah is the second largest state in Malaysia which consists of 13 states and 3 federal territories and the third largest island in the world. Sabah is home to several iconic and rare species such as the Bornean orang-utan, Sumatran rhinoceros, sun bear, proboscis monkey, pygmy elephant, dugong and whale shark, as well as thousands of endemic plants. Sabah is not just a regional and global hotspot for biodiversity, but is also a global hotspot for cultural and linguistic diversity and associated traditional knowledge systems. Known to the world as "THE LAND BELOW THE WIND", Sabah is rich not only in natural beauty and resources, but also in the cultural heritage of its people.

The economy of Sabah has always been heavily dependent on the export of its primary and minimally processed commodities. Aside from the usual lumber milling, the agriculture, tourism and manufacturing sectors are growing vastly, and it is quickly becoming the main source of economy in Sabah. However, petroleum, palm oil and cacao still remained three of the most exported commodities from the state. (Official Website of The Sabah State Government, 2015)

Agriculture is also the main industry in Sabah. The recent financial crisis which Malaysia and the region faced, has highlighted the need for the Sabah state to increase

domestic food production and to be less dependent on imports, to offset the state's increasing food import bills. In this regard, emphasis is given to the enhancement of domestic production of food, in particular paddy as a strategic crop and for food security. At the same time, it is necessary to identify suitable areas for commercial food production to be reserved. Sabah emphasizes sustainable management and utilization of resources as the guiding principle in pursuing agricultural development. In addition, attention is paid to the need to enhance and promote competitiveness in the agricultural sector. Efforts to develop efficient marketing systems and strategies to ensure competitiveness in both local and foreign markets are also to be given greater attention. (Second Sabah Agricultural Policy 1999-2010)

Oil palm is the biggest industry in Sabah. It was first introduced to the State in the early 1960s and in the last three decades, the oil palm industry has contributed significantly to the State's economy. In 2013, the cultivated oil palm area reached 5.23 million hectares in Malaysia, an increase of 3.0% as against 5.08 million hectares recorded in the previous year. Sabah is still the largest oil palm planted state, with 1.48 million hectares or 28% of total oil palm planted area (Review of The Malaysian Oil Palm Industry 2013). Traditionally, Sabah was heavily dependent on lumber based exports, but with the increasing depletion at an alarming rate of the natural forests, ecological efforts to save the remaining natural rainforests areas were made in early 1982.

Eco-tourism is a major contributor to Sabah's economy as well. Sabah has a variety of spots for tourists nationally and internationally, for example Sipadan Island, (a World Heritage Site) and Kinabalu National Park, due to their rich ecosystems of marine life and wildlife habitats.

2.1.1.2 Sabah's Biodiversity

The biodiversity of Sabah emerged over millions of years. Over this time, an astounding diversity of plants, animals and micro-organisms emerged in a range of distinctive ecosystems. The state with its diverse habitats from mist-covered mountain forests, to meandering rivers and floodplains and vibrant underwater kingdoms has become synonymous with nature. Within these ecosystems, we find dynamic assemblages of plants and animals which are delicately inter-connected. Many of these are endemic. Some of these species have become cherished symbols of Sabah and draw millions of domestic and international visitors each year. An exceptional element of biodiversity in Sabah is its long association with the indigenous communities. Over generations, people have accumulated knowledge of plant and animal diversity, ecological relationships and seasonal rhythms. Indigenous communities draw upon this knowledge to extract food, materials and medicines from their surroundings, and retain a remarkable living archive of knowledge. This close connection to nature has also richly influenced cultural traditions and spiritual beliefs, and for this reason this unique biocultural diversity has become inextricably linked to the identity of its people. This biodiversity also provides essential services to enable the people of Sabah to enjoy clean air and water supply, and partake of the bounty of productive ecosystems. It also enables them to sustain their economy.

Sabah's economic structure is heavily dominated by the primary sector and the export of a few commodities, mainly oil and gas. In the gross domestic products in Sabah in 2010, the service sector contributed about 50.4% to Sabah's overall GDP, followed by agriculture at 22.9%, mining and quarrying 16.9%, manufacturing 7.9% and construction at 1.4% (Department of Statistic, Malaysia). In 2010, persons

employed in the agriculture, forestry and fishery sector accounted for 35.0% (Yearbook of Statistic, Sabah 2011).

2.1.1.3 Poverty in Sabah

The rural areas in Sabah have suffered and still suffer poverty, although the government has been making efforts for the last 40 years to alleviate and eradicate it. Rural development in Sabah is always discussed by the government in tandem with poverty eradication.

The Malaysian government's long-term poverty eradication Programs have successfully addressed poverty since the early 1970s. The incidence of poverty in Malaysia declined sharply from 52.4 % in 1970 to 6.1 % in 1997. At present, the nation's incidence of poverty is at a minimal 1.7% as of 2012. The incidence of poverty in Sabah fluctuated around 20% for almost 15 years from the middle of the 1990s (Table 2.1). Although recent Figure (2009 and 2012) show a reduction by half in four years, the latest Figure (8.1% in 2012) is still extremely high in comparison with those in any other state (Figure 2.1).

Table 2.1 Incidence of Poverty in Sabah and Malaysia 1976-2012

Year	1976	1979	1982	1987	1995	1997	1999	2002	2004	2009	2012
Total in Sabah	58.3%	41.1%	29.2%	n.a.	28.71%	21.37%	24.31%	16.00%	24.22%	19.7%	8.1%
Urban	25.9%	21.3%	15.9%	n.a.	15.36%	10.24%	14.25%	9.25%	13.97%	9.8%	5.3%
Rural	65.7%	50.1%	36.1%	n.a.	35.75%	27.72%	30.22%	23.64%	35.79%	32.8%	12.9%
Total in Malaysia	37.7%	37.4%	n.a.	19.4%	8.7%	6.1%	8.5%	6.0%	5.7%	3.8%	1.7%

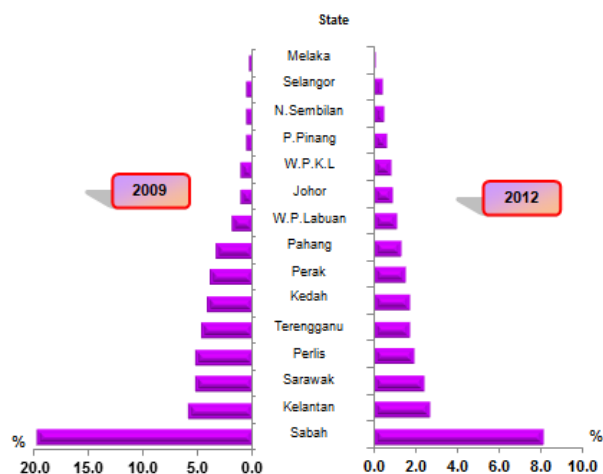
Source: Government of Malaysia, 1984

UKM, 2006

Department of Statistics Malaysia, 2014

Ministry of Tourism, Culture and Environment Sabah, 2014

Economic Planning Unit, 2014



Source: Department of Statistics Malaysia, 2014

Figure 2.1 Incidence of poverty by state, Malaysia 2009 and 2012

2.1.2 Profile of Tudan village, Sabah

2.1.2.1 Background of Site Selection

Tudan village was selected as the case study site. Tudan village (GPS 5°51'45" N, 116°19'53" E) is located on the western slopes of the Crocker Range in the northern section of the Crocker Range Park, and it is 27 km east of Kota Kinabalu, the capital city of Sabah State (Figure 2.2, Photo 2.1 and Photo 2.2). It lies at an elevation of approximately 1,130m above sea level. Administratively, Tudan village is located in Tuaran District. At the moment, Japan International Cooperation Agency (JICA) together with Sabah State Government, and the Malaysian Federal Government is implementing a joint technical cooperation project on Sustainable Development on Biodiversity and Ecosystems Conservation in Sabah (SDBEC) under Japan's Official Development Assistance (ODA), from July 2013 to June 2017 for a four-year cooperation project. Under SDBEC, Tudan village was selected as the first pilot site based on the following five criteria 1) The existence of threatened importance biodiversity / wildlife; 2) A high potential for livelihood improvement; 3) The willingness to participate in the Project among local stakeholders and adequate local governments' commitments; 4) Relatively easy access and a high display potential as a model; and 5) No similar major projects in the area, In the meantime, Crocker Range Park and its surrounding areas called Crocker Range Biosphere Reserve (CRBR) was designated as a Biosphere Reserve under the Man and Biosphere (MAB) program in June 2014, UNESCO (core zone: 144,492ha, the buffer zone: 60,313 ha, the transition zone: 145,779ha), and Tudan village is located in the buffer zone of CRBR. In light of MAB concept, a buffer zone is a place where people's livelihoods are enhanced and at

the same time environmental sustainability is ensured. In other words, the buffer zone of the MAB is a place where human-nature interactive relations exist where the SEPLS is dynamic. Under the UNESCO principle, the MAB should conserve biodiversity and local culture through appropriate land management and sustainable development. In addition, global network for biodiversity and ecosystem research, education, and training needs to be developed. Considering these UNESCO MAB principles, JICA is implementing the pilot project for the livelihood improvement and community-based conservation in Tudan village through activities such as making compost for agriculture improvement, capacity building for locals and government officials; policy support; support for local governance; and environmental education in collaboration with the Tuaran local District Office and other various stakeholders including local communities at Tudan village.

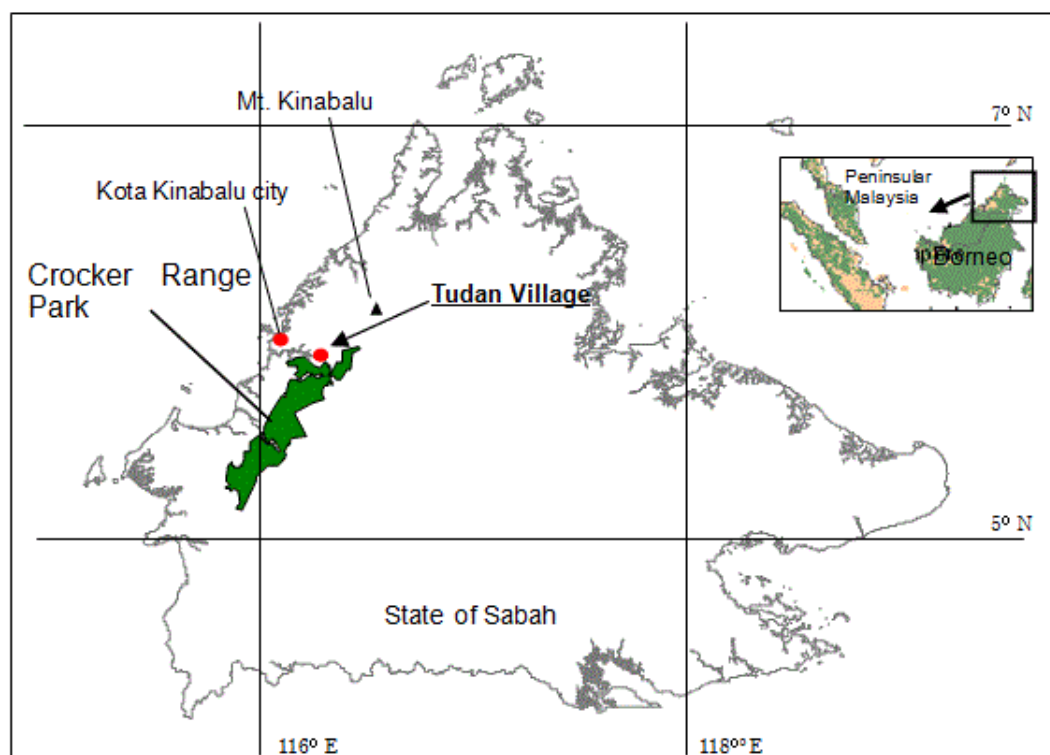


Figure 2.2 Research site



Photo 2.1 Landscape of Tudan Village (photo credit: Kazunobu Suzuki)



Photo 2.2 Landscape of Tudan Village (photo credit: Kazunobu Suzuki)

2.1.2.2 Infrastructure

Tudan village is easily accessible by a paved road, completed in 2012, which heads directly into the village for approx. 3.8km off the Federal Road 500. All houses in the main village area and along the roads were supplied with electricity from the main grid in late 2013. Water is however supplied using gravity feed which is tapped and piped into houses from the main tributary of the Libodon River. There are a host of community facilities in the village although there is only a single school at the primary level. Secondary students are therefore sent to residential schools in Kiulu, Bundu Tuhan and Tambunan. The village has a Church, a church hall and a community hall. There is no public transportation although buses can be caught along the Federal Road 500.

2.1.2.3 Land Use

The landscape within the boundaries of Tudan village consists of farmland, old growth forests and the village area (Table 2.2, Figure 2.3). The old growth forests are areas that have been left under long fallow and are located along the upper slopes of the village boundaries. Farmland consists of plots that are presently under active use and will in the future be returned to fallow. The village area represents the central region of the Tudan village where a cluster of houses can be found. However, there are a number of houses which are located further away on the slopes of the village as well as newer houses that have been built along the main road.

No.	Land Use	Area (in hectares)
1.	Active Farmland	260.59
2.	Old Growth Forest	189.90
3.	Village Area	30.33
	<i>Total</i>	480.81

Table 2.2 Land use within Tudan Village (Source: SDBEC)

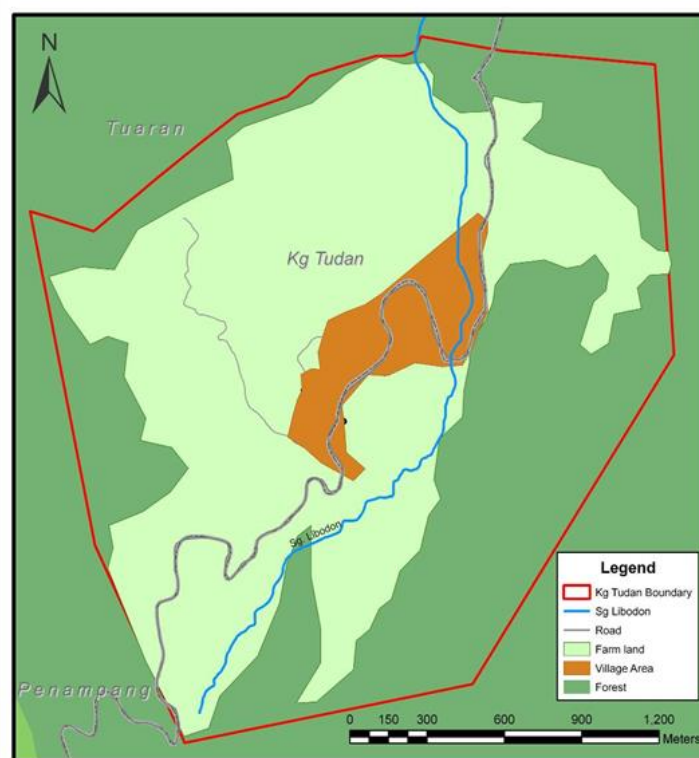


Figure 2.3 Land use within Tudan Village (Source: SDBEC)

2.1.2.4 Population and Households

Tudan village's recorded population is 315 persons with 42 households (as of 2014) . However, the number of 'permanent' residents and occupied houses is less as many adults work in larger towns such as Tambunan and Penampang district only to come back to the village on weekends, while youngsters have also moved out to seek jobs elsewhere, including in Peninsular Malaysia.

2.1.2.5 Ethnicity and Religion

The local community of Tudan village is of Dusun ethnicity and Christians from the Roman Catholic denomination with the exception of a single family who are Seventh Day Adventists. However, intermarriages with partners from outside the village have resulted in many families having members who practice different faiths such as Islam. Tudan village's younger generation demonstrates sufficient fluency in Bahasa Malaysia; however there are many senior members of the community who are only fluent in the Dusun language.

2.1.2.6 Socio-Economy

Swidden-based rice farming was largely a major characteristic of the traditional agricultural system in Tudan village. Swidden-based farming is carried out by rotating agricultural plots under a fallow system where the same plots are utilized by a family. Although important in the past, its dominance is declining as economic levels have increased, providing greater access to goods externally, coupled with the lack of labor among households to work the fields. Agriculture is however more diversified today

where a variety of crops are being grown for both local consumption and for nearby markets. The majority of the community still remains as farmers.

2.1.2.7 Culture and Tradition

Almost all community members have embraced forms of institutionalized religion; however there are some animist practices and observances that have endured. *Adat* (moral and customary law that govern the indigenous communities) continues to play a central role in governing the daily lives of the communities, for example in communal work which is now organized for the upkeep of the village common areas and facilities. There was however concern that the younger generations are losing interest in traditional knowledge and traditional ways of living.

Session 2.2 Data collection and data analysis

2.2.1 Evaluation of biomass energy potential in Sabah

2.2.1.1 Data collection

Data were collected from official publications such as the Yearbook of Statistics Sabah 2011, Report on Crops Hectarage and Production in Sabah 2010, Malaysian Oil Palm Statistics 2013, and Sabah Electricity Supply, Industry Outlook 2014. Some data not found in official publications were collected from individual hearings prepared by organizations/agencies concerned. In cases where basic energy information and data were unavailable in Sabah, reference data were collected from official documents that were available in Japan. Among the potential biomass sources, collected data included oil palm, coconut shell, rice, livestock (buffalo, cow, goat, and pig), and forest. Published statistic data were mostly dated in 2010. Data of 24 districts were collected while data on livestock were obtained from 32 districts and sub-districts in total. Thus, to perform quantitative evaluations in a consistent way, this difference was adjusted by integrating data of some districts and sub-districts such as Menumbok, Membakut, Bongawan, Pulau Banggi, Telupid, Sook, and Putatan into one with their administratively neighboring districts.

2.2.1.2 Data analysis and calculation

The energy conversion factor (Calorie or Joule per kg or tonne) that corresponded with each type of biomass was identified. Then, the amount of energy from each type of biomass was calculated as follows.

(i) Oil palm

In the process where oil is extracted from dry fresh fruit bunch (FFB) and water, various products such as crude oil, mesocarp fiber, seeds, shell, empty fruit bunch (EFB), and dirt are produced. Among such products, EFB and shell are regarded as potential sources of biomass energy. Malaysian Oil Palm Statistics stated that FFB in Sabah constituted 20.16 tonne per hectare in 2010. As oil palm area found in the official statistics amounts to 1,414,624.9 hectares, around 30 million tonnes of FFB is produced. From 100 kg of FFB, 23 kg of EFB and 7 kg of shell, which can be used as biomass, can be produced (Cater, 2014). Based on these distributions, 6.9 M tonnes and 2.1 M tonnes of EFB and shell are annually produced in Sabah, respectively.

The calorie conversion factor of biomass (EFB and shell) is defined as 4,300kcal/kg (Agency for Natural Resources and Energy, 2015). Given that EFB and shell contained approximately 60% and 30% water, respectively and that the latent heat of water (neglecting sensitive heat) is 560 kcal/kg, the calorie per kg of EFB and shell was calculated to be 1,400 kcal/kg ($4,300 \times 0.4 - 0.6 \times 560$) and 2,800 kcal/kg ($4,300 \times 0.7 - 0.3 \times 560$), respectively.

(ii) Coconut Shell

In coconut shell, 1.8 M tonnes of the shell were produced from 14.8 M tonnes of coconut in the case of a project in Philippines (New Energy Foundation, 2015). Using this ratio, the amount of coconut shell in Sabah was measured. The calorie conversion factor (kcal per kg) was obtained from the Someya Corporation case (3,500–4,000 kcal/kg) (Someya Corporation, 2015), and then it was averaged to 3,750 kcal/kg.

(iii) Rice

A report on Crops Hectarage and Production in Sabah (2010) presented findings on paddy and rice production. The ratio of rice to paddy production was around 63% in all districts. Here, although it is a rough calculation, the remainder (37%) was regarded as potential biomass energy. Considering this was rice husk, an energy conversion factor of 14.2 GJ/tonne was used as a reference from a practical case in Japan (NEDO, 2015).

(iv) Livestock (buffalo, cow, goat, and pig)

Biogas from livestock waste can be considered as biomass energy. The number of livestock was obtained from the Department of Veterinary Services and Animal Industry, Sabah. As it was difficult to find an energy conversion factor in official publications in Sabah, available Figures from research papers and documents in Japan were used for the calculation (Hokkaido Biomass Research Group, 2002 and AIST, 2010). Buffalo and cow have the same energy conversion factor of 7,665 MJ/year/head, while factors of 1,260 MJ/year/head for goats and 1,533 MJ/year/head for pigs were used.

(v) Forest

The Sabah Forestry Department publishes an annual report on forest reserves and other types of forested lands (Annual Report 2010). Forest reserves are categorized into seven types: Protection Forest Reserve, Commercial Forest Reserve, Domestic Forest Reserve, Amenity Forest Reserve, Mangrove Forest Reserve, Virgin Jungle Reserve, and Wildlife Reserve. Other forested lands include Sabah Parks, Wildlife Sanctuary, Wildlife Conservation Area, and Timber Plantation. Most of the forest reserves are protected areas that are strictly regulated with respect to the usage of forest resources

inside the reserves. Among these forest reserves, data on commercial Forest Reserve, Domestic Forest Reserve, and Timber Plantation, which are subject to use in a sustainable manner, were analyzed in this study to estimate the associated amount of forest-driven biomass potential energy. Even though it is a small area compared to the aforementioned forest reserves, forests outside the protected area are also important. However, these areas were not accounted for in this thesis, because no data is available to estimate these areas in a comprehensive way. An energy conversion factor of 0.7 GJ/ha was used (Sato, 2010).

2.2.2 Evaluation of energy based food self-sufficiency potential in Sabah

2.2.2.1 Data collection

Data were collected from official publications such as the Yearbook of Statistics Sabah, Report on Crops Hectareage and Production in Sabah, and Annual Fisheries Statistics. Some data which were not found in the official publications were collected through separate and individual meetings with organizations/agencies concerned. Collected data include 1) industrial crops (Coconut, Cocoa, Coffee, Paddy, Sugar Cane, Tea, Tobacco and Sago); 2) agricultural crops (Fruit Crops - 34 species, Leafy Vegetables - 28 species, Fruit Vegetables - 18 species, Root Vegetables - 3 species, Cash Crops - 6 species, and Spices - 14 species); 3) livestock (Buffalo Beef, Cattle Beef, Pork, Chicken Meat, Duck Meat, Chicken Eggs, Duck Eggs and Liquid Milk); 4) fish (Landings of Marine Fish, Brackish water, Seaweed and freshwater fish). Published

statistical data were mostly dated 2010 and data of 24 districts were collected. Rubber and oil palm which were categorized as industrial crops were not included in this research. It is partly because rubber can be considered as a non-food product. It is sometimes debatable whether or not oil palm is food. If oil palm is regarded as food, then the self-sufficiency ratio of food is more than 100% in all districts (even 19,282 % at Beluran district) except for Kota Kinabalu and Penampang district. Considering that palm oil calorie contributes to a meaningless conclusion in terms of energy based total self-sufficiency of food, palm oil was not included in this research.

Data on livestock was gained from the Department of Veterinary Services and Animal Industry, Sabah since such data was not found in the official publications. The Department merged some districts into one. Kunak, Kinabatangan, Beluran, Sipitang and Nabawan were merged with Tawau, Sandakan, Sandakan, Beaufort and Keningau, respectively. Data on fish has the same issue. Data on landings of marine fish was available in only 16 districts. No data in 8 districts, namely Kinabatangan, Tongod, Ranau, Penampang, Tenom, Keningau, Tambunan, Nabawan was available.

2.2.2.2 Data analysis and calculation

Figure on food calorie were basically referred to in official publications such as Nutrient Composition of Malaysian Foods 4th Edition. Where figure were not available in Sabah or Malaysia, the food calorie figure available in Japan were applied. By using such calorie figure, the supplied calorie of industrial crops, agricultural crops, livestock and fish at all 24 districts was calculated. Then the necessary calorie based on

population was calculated. Finally, the self-sufficient food ratio was calculated based on the supply and consumption calorie.

2.2.3 Analysis of energy consumption and biomass energy potential at Tudan village

2.2.3.1 Data collection

Data such as usage of electricity, gas, gasoline, diesel and firewood were collected based on field visits and hearing from local communities at the Tudan village by a researcher intensively from May 2014 to June 2016.

2.2.3.2 Data analysis and calculation

Based on data collected, energy consumption (electricity, gas, gasoline, diesel and firewood) and potential biomass energy derived from forest, livestock and rice husk at Tudan village were analyzed and calculated as follows. In this case, 36 was applied as the number of households in the village because some of the house owners were temporary residents, who mainly stayed outside of the village and only stayed on weekends or a few times per month.

Firstly, energy consumption or energy amount used (joule/year /household) was calculated.

(i) Electricity

Amount used at the village was 70 KW/h/month/household on average. By applying 1KW equals 0.86 M calorie and 1 calorie equals 4.19 joule, electricity amount used was 3,026 MJoule/year/households.

(ii) Gas

Amount of gas used in the village was 1 tank/3 months/household. Gas tank distributed in the village contained 12 kg of gas. Gas in the tank is made up of 70% propane and 30% butane. Considering that the energy of propane and butane was both 12 Mcal/kg, gas amount used was calculated as 2,413 MJoule/year/household.

(iii) Gasoline

Amount of gasoline used in the village was 120 RM (RM: Malaysian Ringgit)/month/household. In Sabah, 1 liter of gasoline equals 2.1 RM on average, thus 57 liter of gasoline was used per month by one household. Considering that 1 liter of gasoline equals 0.75kg and 1g of gasoline equals 11.3kcal, gasoline amount used was calculated as 24,348 MJoule/year/households.

(iv) Diesel

Calculation can be done in the same manner as gasoline. Amount of diesel used in the village was 40 RM (RM: Malaysian Ringgit)/month/household. In Sabah, 1 liter of diesel equals 1.8 RM on average, thus 22 liter of diesel was used per month by one household. Considering that 1 liter of diesel equals 0.80kg and 1g of diesel equals 10.7kcal, diesel amount used was calculated as 9,564 MJoule/year/household.

(v) Firewood

Community members in the village collected firewood from the forest mainly for cooking. Amount collected was around 2 to 4 kg per day per household. Being averaged to 3.5 kg per day per household and using the energy conservation factor for wooden chips as 7.0 MJoule/kg (Miyazaki Prefecture, 2015), the firewood amount used was calculated as 8,943 MJoule/year/household.

Secondly, the biomass energy potential (joule/year /household) at Tudan village was calculated.

(i) Forest

Tudan village has 189.90 hectare of forest (Table 2.2). By applying the energy conversion factor of 0.7 GJoule/hectare (Sato, 2010), the energy potential derived from the forest was 3,693 MJoule/year/household.

(ii) Livestock

Tudan village has pigs and chicken as livestock. Biogas from livestock waste was considered as biomass energy. Biogas from chicken is very small in amount, thus only waste from pigs was considered. Tudan village has an average of 20 pigs per household. As it was extremely difficult to find an energy conversion factor in the official publication in Sabah, the available figure from research papers in Japan was used for calculation. Considering that one pig produces 0.2m^3 waste /day and $5,000\text{Kcal}/\text{m}^3$, the energy potential derived from pig waste was 30,660 MJoule/year/household.

(iii) Rice husk

Tudan village produces around 15 sacks of rice per household annually. Assuming that 1 sack is 20kg, total rice production at Tudan village is 300kg/year/household. Report on Crops Hectarage and Production in Sabah (2010) showed paddy and rice production with the ratio of rice to paddy production around 63% in all districts. Here, although it is a rough calculation, the rest (37%) was regarded as a potential for biomass energy. Considering this was rice husk, the energy conversion factor, 14.2 GJ/tonne was used by reference from the practical case in Japan (NEDO, 2015), and then energy potential derived from rice husk was 1,576MJoule/year/household.

2.2.4 Analysis of Social Capital (Happiness degree) at Tudan village

2.2.4.1 Data collection

Data was collected by a researcher based on field visits. Data collection by SADT was made on May 7, 2014 by a researcher through interviews with the help of a representative from the local community. The questionnaire of Happiness Survey was prepared in reference to some advanced case studies, and was distributed to 19 local community members on May 27, 2014.

2.2.4.2 Data analysis

In general, data was analyzed in English. Raw data from the local community was translated from Bahasa Malaysia or the Dusun language. The results were utilized to classify the communities of Tudan village into Satoyama like, in transition, or non-compliant based on the SADT developed by Dublin and Tanaka (2014a) from the five perspectives as advanced by the IPSI. These are: Cyclic use of Natural Resources; Resource Use based on Carrying Capacity and Resilience of Environment; Recognition of the Importance and Value of Local Cultures and Traditions; Collaborative Management of Natural Resources; and Contribution to Local Socio-Economies. As stated by Dublin and Tanaka (2014a,), the SADT was developed to estimate the criteria of the five perspectives, which comprises of a questionnaire, a definition of the community classification type, and solutions for resolving problems encountered based on the Millennium Development goals (MDGs). After identifying some characteristics in the context of Satoyama Agriculture Development by the SADT, a questionnaire was prepared and a survey entitled the “Happiness Survey” was conducted, which covered some representatives of the village to explore more human interactions with nature. Happiness Survey was designed for aiming at understanding the level of satisfaction of the local community in their daily life, and the questions in the survey focused on two aspects, namely the village in general, and the community’s behavior and awareness totaling 67 questions. All responses were graded (scored), and averaged by actual observed data and expectations. Then these were compared for statistical differences. As a result, items that showed significant differences between actual observed data and expectations were identified as ones to be carefully considered for project designing.

Differences between male and female were also analyzed by applying the Exact Wilcoxon Test. Furthermore, answers “free description” were summarized.

2.2.5 Analysis of Natural Capital at Tudan village

2.2.5.1 Data collection

Data were collected by a researcher based on field visits and interviews from local community members from September 2015 to November 2015 as well as through official publications that were available both in Sabah, Malaysia and in Japan. Notable references from Japan were the Japan wood energy Co.,Ltd. (2015), SHIMOKAWA Research Institute for Forest and Future Society (2013), Laurence Chase (2012) and Hasegwa (2012). Some data which were not found in the official publications were collected from separate and individual hearing with organizations and agencies concerned.

2.2.5.2 Data analysis and calculation

Most of the data were analyzed and calculated in reference to the Natural Capital Evaluation Report in Shimokawa Town, Hokkaido (SHIMOKAWA Research Institute for Forest and Future Society, 2013). Two functions of Natural capital, namely public interest functions of forests and public interest functions of agricultural land were analyzed.

Chapter 3 Results and Discussion

Session 3.1 Evaluation of biomass energy potential in Sabah

3.1.1 Introduction

In the twentieth century, large amounts of natural resources, including food and energy, were used to sustain mass amounts of production, consumption, and disposal. Considering resource limitations on Earth in the years to come, this way of life has to be changed; in response, there has been a growing recognition and a pressing need to build more sustainable societies, where the use of limited resources is optimized. One factor that is fundamental to the development of a sustainable society is to decrease, or at least not increase, the total amount of energy used. Another factor is to reduce the dependence on petroleum as a source of energy (Shiotsu, 2011). A comparison has also been made where current agricultural practices may be defined as a “conversion of oil into food” (Saito, 2009). In light of these realizations, our challenge is to reduce our current dependence on petroleum as a source of energy. In other words, our society requires food and energy independence, so that the area either at national, regional, or local level can become independent both agriculturally and in terms of energy usage (Osaki, 2011a).

The National Renewable Energy Policy and Action Plan in Malaysia stated that renewable energy in Malaysia had an insignificant impact on power generation. Ensuring the nation’s sufficient and affordable supply of energy is paramount to its stability with respect to economic development on a national level. Until now, renewable energy facilities were not able to compete with conventional energy in terms

of scalable production. Furthermore, the production of renewable energy is expensive compared with that of conventional energy. For instance, coal is a more economic source, and there are large coal reserves globally. However, since coal adversely affects the environment (i.e., CO₂ emission and its contribution to air pollution), it is not considered to be a form of sustainable energy. The continuation of Malaysia's use of natural gas as fuel for energy generation cannot be sustained for the long term because of limited reserves. In addition, the impact of using carbon-based fuels for energy generation has already led to observable environmental degradation and climate change. Thus, it is imperative for Malaysia to consider renewable energy as an alternative source of fuel for future power generation. As Malaysia is the second largest producer and the largest exporter of crude palm oil, biomass in the form of oil palm residue has significant potential as a form of renewable energy. Finally, the development cost for renewable energy is expected to decline whilst the development cost for conventional energy is expected to rise (National Renewable Energy & Action Plan, 2008).

Malaysia is blessed with many indigenous sources of renewable energy, including 1) biomass and biomaterials from oil palm residues, palm oil mill effluents, forestry biomass, solid waste, and waste from agro-based and farming industries, 2) mini-hydro power, 3) solar power, and 4) wind energy. While the country has identified a range of potential energy sources, detailed and comprehensive investigations are required to confirm their viability (National Renewable Energy & Action Plan, 2008). This research was conducted to evaluate the potential for power generation with renewable energy for the first time at each district in Sabah, focusing on biomass energy among a variety of renewable sources on site.

3.1.2 Result

The biomass energy potential in Sabah was calculated by district (Table 3.1). The energy unit here was standardized as Giga Joule per year (GJ/year). Then, the potential of electric power (MWh), which can be produced by each biomass was also calculated (Table 3.2 and Figure 3.1).

As shown in Table 3.1, the biomass energy potential in Sabah is around 65,590,323 GJ/year, which was derived from oil palm EFB and shell, coconut shell, rice, livestock, and forest. Eastern parts of Sabah such as Kinabatangan and Lahad Datu District has significant potential. Most biomass energy came from oil palm, which produced around 62,045,584 GJ/year or 94.6% out of the total biomass potential energy (Figure 3.1). If this total energy potential is applied at a power plant with an efficiency ratio of 25% and 8,000 hour per year of operation, it will have a potential of 572 MW, as shown in Table 3.2, which is equivalent to the electric power produced by one small nuclear plant in Japan. This amount of energy is equivalent to around 90% of the total supply of electricity in 2010 ($5,105.4 \text{ GWh}/8000 \text{ h} = 638 \text{ MW}$) in Sabah.

Since the feed-in-tariff rate for biomass is around 0.27 RM per KWh (Ministry of Energy, Green Technology and Water), if this total biomass-derived energy potential is translated into financial terms, it is equivalent to around 1,240 Million RM per year (1RM (Malaysian Ringgit) = 0.24USD, as of October 2015).

Districts	Oil Palm	Coconut Shell	Rice	Livestock				Unit (GJ/year)	
				Buffalo	Cow	Goat	Pig	Livestock (total)	Forest
Tawau	7,565,568	6,333		1,533	46,404	12,356	25,459	85,751	193536
Sempoma	2,158,158	11,166		337	5,733	5,471	0	11,542	0
Lahad Datu	12,241,721	11,631		24,045	151,782	13,473	6,308	195,609	141328
Kunak	3,492,022	138		2,491	12,824	2,972	0	18,287	1618
Sandakan	5,443,424	2,464		2,721	4,982	5,019	21,335	34,057	0
Kinabatangan	14,577,113	352		7,128	15,506	1,664	0	24,299	106327
Tongod	1,194,183	29	14,527	161	5,396	488	8	6,052	509429
Beluran	12,037,276	1,172	4,217	9,275	6,753	3,059	233	19,320	223978
Kudat	257,248	25,844	12,027	3,296	12,356	1,507	2,592	19,751	8677
Pitas	190,476	19,478	56,729	751	7,841	348	169	9,109	53531
Kota Marudu	232,432	8,842	108,247	8,286	10,148	3,056	2,879	24,369	16765
Kota Belud	20,921	580	173,723	14,893	29,326	347	287	44,853	0
Ranau	81,137	287	50,694	8,332	8,531	1,109	253	18,225	68826
Tuaran	18,763	201	31,950	11,452	3,718	2,294	34,279	51,743	1029
Kota Kinabalu	0	34	582	2,713	621	2,039	31,354	36,727	0
Penampang	215	0	8,463	3,710	1,165	1,944	5,625	12,444	0
Papar	211,037	1,218	16,486	6,768	3,419	5,468	13,080	28,735	1029
Beaufort	871,022	1,359	16,614	11,681	3,104	3,184	886	18,856	21030
Sipitang	19,439	582	22,365	2,123	881	987	83	4,074	124563
Kuala Penyu	89,681	3,755	1,860	5,297	797	886	1,473	8,453	0
Tenom	218,906	0	66,825	261	9,796	1,270	934	12,260	79414
Keningau	961,685	213	69,140	5,802	41,590	4,913	650	52,955	83679
Tambunan	11,452	30	41,791	4,108	4,085	651	622	9,468	19707
Nabawan	151,703	5	13,788	2,016	943	736	64	3,759	333835
Sub Total	62,045,584	95,713	710,028	139,181	387,703	75,240	148,572	750,696	1,988,301
Total	65,590,323								

Table 3.1 Biomass potential energy by district in Sabah

Unit (MWh)	
Oil Palm	541
Coconut Shell	1
Rice	6
Livestock	7
Forest	17
Total	572

Table 3.2 Electricity potential by biomass

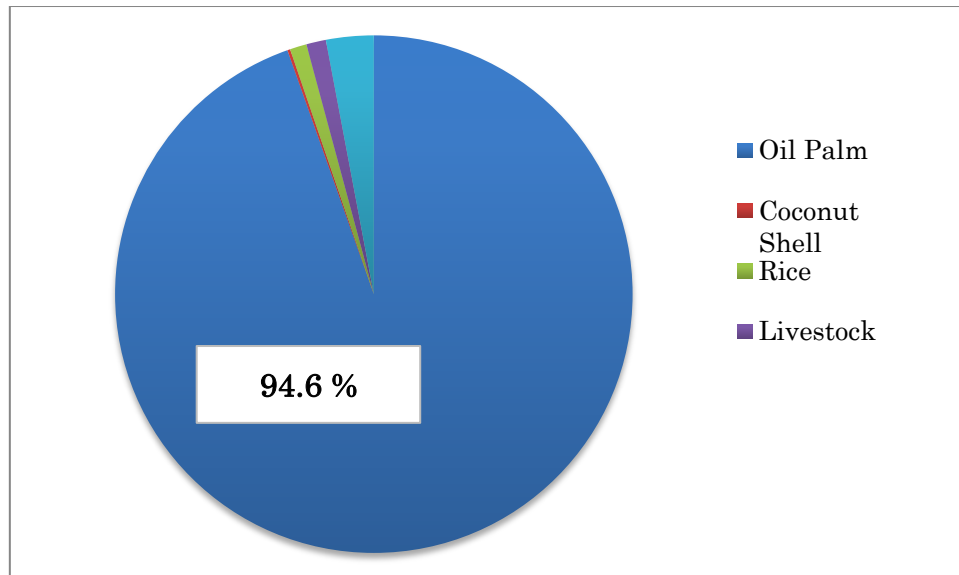


Figure 3.1 Percentage of potential energy by biomass

3.1.3 Discussion

This thesis estimates the biomass energy potential in Sabah, and provides reliable and realistic Figures to support the analysis of the current situation. Based on these Figures, it is possible to consider future actions for the first time, and to demonstrate that Sabah definitely has significant biomass energy potential.

The eastern part of Sabah has an even more significant biomass energy potential than the other parts, because the oil palm plantation area in the eastern part is the largest. If current facilities or oil palm mills can also manage to produce energy from EFB and shell, they would be able to provide energy for other areas, some of which are suffering from the shortage of electricity, such as villages in the rural area. This might be a good scenario for designing policy and making region-wide strategic plans for energy security in Sabah. With regards to designing a sustainable society, it is necessary to make decisions about resource allocation (Sumi, 2011). However, this might not be so easy, as the cost and time required for collecting and transporting biomass for its distribution should be considered. Nevertheless, there is room for technological innovations to effectively use such types of biomass and to develop a social base that would include production, distribution, and use of the biomass within local areas in future. Modern and efficient boiler and turbine systems that use biomass and biogas captured from anaerobic effluent treatments can provide the steam and electricity required for palm oil mill operations. The solid biomass residues can be channeled to the production of value-added products such as biofertilizers, biochar, biofuels, and biomaterials. The final liquid discharge can be further treated to meet river water quality standards, making it suitable to be recycled, toward achieving zero emissions (Ahmad, 2015). Furthermore, a new oil palm industry can be established. EFB can be used as an

organic fertilizer, since it contains much potassium (Shirai, 2009). Such a new industry has the potential to create new job opportunities, thereby activating the regional economy and helping to alleviate poverty. A scenario where an additional 20 million tonnes of oil palm biomass is required by 2020 for higher-value uses could have the potential to contribute significantly to the Malaysian economy (National Biomass Strategy 2020, 2013). Coconut shell, rice husk, and livestock, although a source with less potential than that of oil palm, can be used as compost materials. Forest-derived biomass such as firewood is actually used as an energy source in the daily lives of people who live inside or near the forest, and biochar made from bamboo, for example, is traditionally used in rural area in Sabah. Sustainable use of forest resources can contribute to sustainable life and agricultural practices. On a more global scale, the promotion of biomass energy can help address climate changes.

Nowadays we face the challenge of how to realize a functional society with renewable energy because of the recognition that a society that is dependent on petroleum is absolutely unsustainable and leads to the depletion of limited resources. Given this realization, renewable energy is a possible or even indispensable solution toward promoting the sustainable use of resources. Biomass energy is one of the promising renewable energy sources along with solar power energy and small-scale hydro power energy. It is attracting attention as a method of preparing for the depletion of fossil fuels (Osaki, 2011b). Biomass is a stable, safe, and sustainable energy resource and offer numerous important advantages in terms of storage, transportation, and conversion to gas and liquid forms. In addition, it allows for local production and consumption (Nitta, 2011).

Malaysia has access to several types of renewable energy. The capacity of small-scale hydro power stations in Sabah is around 8.335 MW (National Renewable Energy Policy & Action Plan, 2008). This highlights the significantly large electric potential of biomass. On the contrary, a reasonable target for grid-connected solar photovoltaic as a building integrated application is 850 MW by 2030 (National Renewable Energy Policy & Action Plan, 2008). However, the solar power potential estimation in Malaysia indicates that the constraint is not so much dependent on the availability of solar irradiation, but more on the availability of funding and the ability of domestic and international production facilities to cope with its demand (National Renewable Energy Policy & Action Plan, 2008). Considering the implications of these factors, biomass energy as a future alternative is promising.

3.1.4 Conclusion

In conclusion, this research is the first of its kind to provide an overview of biomass energy potential in Sabah, Malaysia. The result in this research could be a driving force to increase public awareness about the effective use of biomass. Hopefully, with critical consideration of both advantages and current limitations, this research can also provide guidance on what subsequent actions can be taken to further maximize the potential of this resource. This can include the designing of relevant policies or plans, and the development of innovative technologies. The research emphasizes on the significant potential of biomass as a source of renewable energy in Sabah, especially if customized policies or plans are designed to integrate its use fully within the society. Furthermore, the development of innovative biomass-based technologies could be applied to conserve the environment.

Session 3.2 Evaluation of energy based food self-sufficiency potential in Sabah

3.2.1 Introduction

As stated in 3.1.1, our society requires food independence so that the area at either the national, regional or local level can become independent both materially and in terms of energy usage (Osaki, 2011). Population growth is another big factor which gives a high influence on food security. The expansion of food production and the improvement on farming productivity is, of course, indispensable for feeding growing populations. It is not too much to say that we are facing critical challenges in relation to food security. Food is the important material which is concerned with the national welfare and the people's livelihood and social stability (Shutao, 2010). Investment in agriculture remains critical to sustainable long-term food security. Food security is the basic guarantee for the national security (FAO, 2011). Sabah State, Malaysia is such a case. Agriculture and Food Industries Minister said in the Daily Express newspaper dated 15th June, 2015 that the production of food especially staples such as rice in the state remains the focus of the State Government, and the state has been suffering from the shortage of food. Therefore, the state is still importing food to meet the State's needs. He also said that the State policy was to continuously improve the self-sufficiency level through increased productivity and increasing the areas under cultivation. It is pointed out that the Malaysian policy, namely the National Food Security Policy places priority on paddy and rice production, especially in Sabah in terms of food security, and that the

policy measures targeted area expansion and productivity for securing sufficient food (Tey, 2010).

Considering the above, this thesis examined the potential of the self-sufficiency of food to visualize the situation of food security in Sabah and identified some challenges in the future for food security.

3.2.2 Result

3.1 Self-sufficiency Food Ratio

Total Industrial Crop Supply, Total Agricultural Crop Supply, Total Livestock Supply and Total Fish Supply were 408,055 Gcal, 180,334 Gcal, 200,652 Gcal and 158,673 Gcal, respectively (Appendix 1). In terms of area balance, eastern parts in Sabah were in a critical situation from the food supply point of view except for livestock while the western and northern parts had a relatively good potential for food production. Considering the population in Sabah, the self-sufficient food ratio was calculated based on the supply and consumption calorie. The result was 46.4 0%. The ratio in each district is shown in Table 3.3, Figure 3.2 and Figure 3.3.

District	Self-sufficiency ratio (%)	District	Self-sufficiency ratio (%)
Tawau	37	Ranau	97
Sempoma	34	Tuaran	95
Lahad Datu	24	Kota Kinabalu	25
Kunak	36	Penampang	18
Sandakan	17	Papar	90
Kinabatangan	0.2	Beaufout	105
Tongod	30	Sipitang	94
Beluran	11	Kuala Penyu	178
Kudat	767	Tenom	109
Pitas	153	Keningau	39
Kota Marudu	121	Tambunan	81
Kota Belud	147	Nabawan	30
Total food self-sufficiency ratio: 46 %			

Table 3.3 Food self-sufficiency ratio at each district

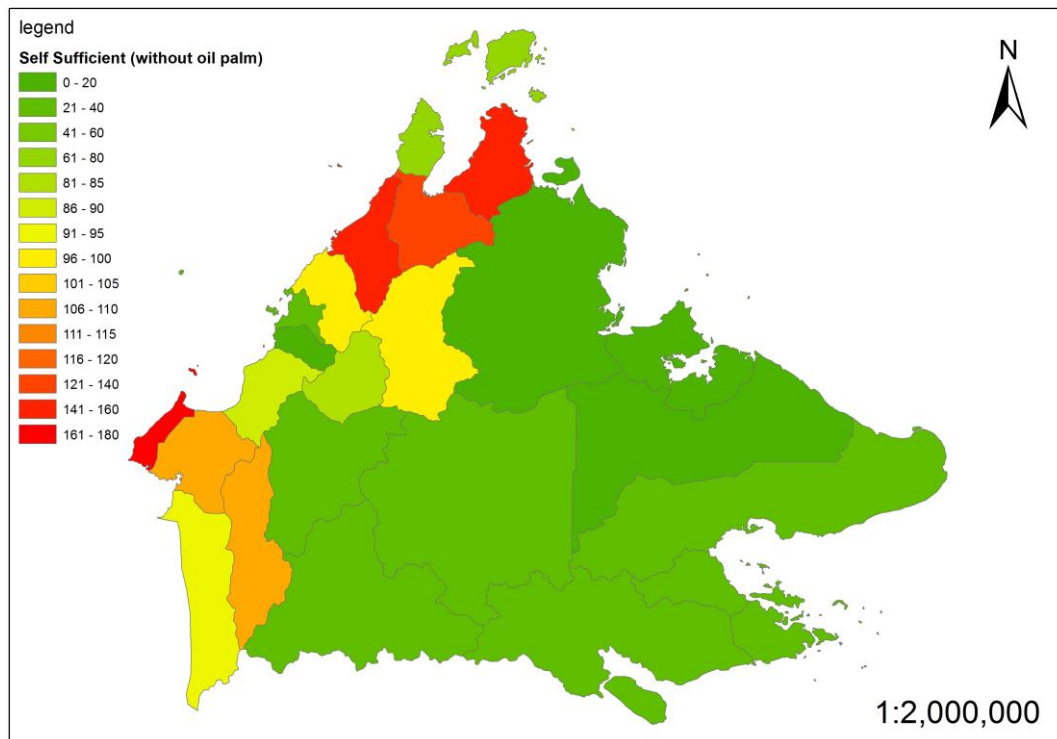


Figure 3.2 Self-sufficiency Food ratio at each district

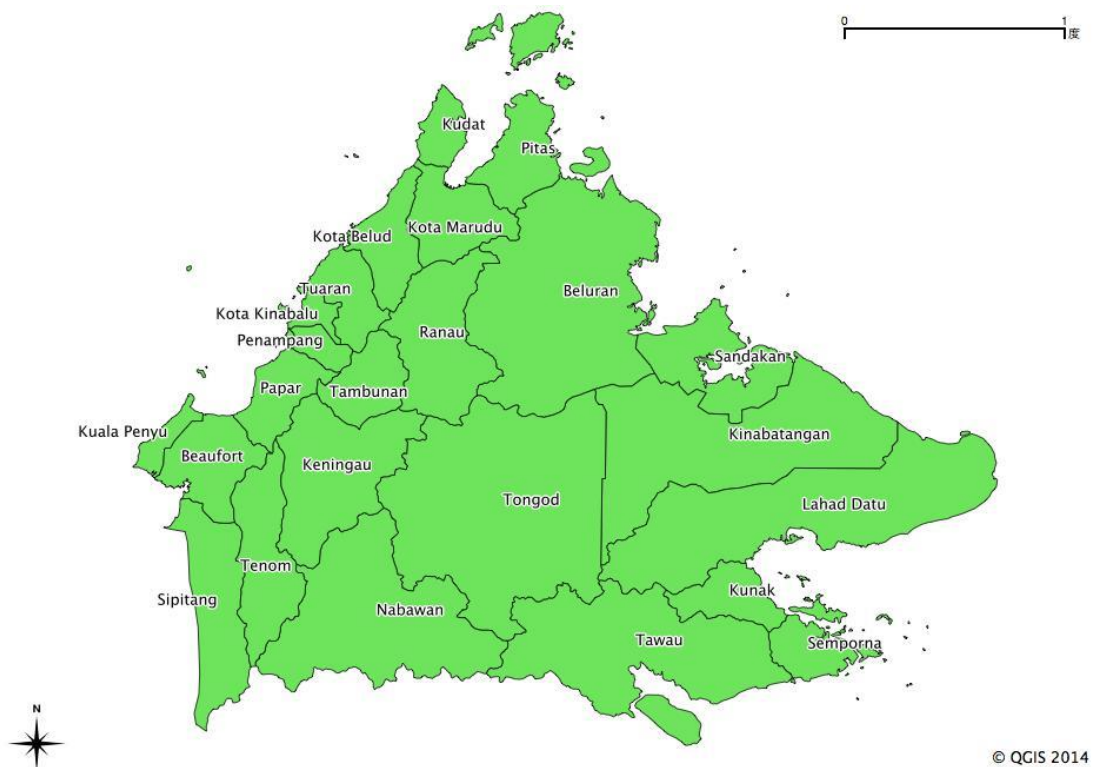


Figure 3.3 Reference: Sabah Map

Some districts, most of which are located in the western and northern part in Sabah, have more than 100% ratio, indicating that such districts such as Kuala Penyu, Pitas and Kota Belud have the capacity to accommodate people with sufficient food. On the contrary, most of the eastern parts are in a very critical situation. Especially, Kinabatangan, Kunak and Sandakan are the worst districts. It should be reminded, however, that data of livestock in Kunak and Kinabatangan was not available and that data of Kunak and Kinabatangan might have been integrated into that of Sandakan. Nevertheless, though inconsistent statistical data was found, Kinabatangan, Kunak and Sandakan districts had reached a critical food supply shortage. In these districts, more than half of the terrestrial areas were covered by oil palm plantation (in case of Kunak, 70.21% of total area was for oil palm.) and had no sufficient land for food production. More seriously, population growth at these districts was quite high compared to other districts. For example, average annual population growth rate from 2000 to 2010 at Kinabatangan District was 4.4% while average of whole Sabah during same period was 2.1%. Limited area for food production and high population growth were a big driving force to accelerate the decrease in local food supply.

3.2.3 Discussion

As for the self-sufficiency food ratio based on supply and consumption calorie, population growth and land for food production might be a factor giving a big impact on the ratio. Recognizing this, a rough simulation was carried out for future forecast. The first case was based on the scenario that the population in Sabah continues at the pace of 2%. In this case, self-sufficiency food ratio would be slightly down to 45.49 % from

46.40% (Appendix 2). Considering that rice remained as the most important staple in Sabah as Agriculture and Food Industries Minister in Sabah said, next scenario was designed for taking the area for rice production into consideration. In addition to continued population growth of 2%, if rice production area decreased by 5 % per year, calculation indicated that the ratio goes down to 44.47% (Appendix 3). Though it was a rough simulation, there is no doubt that population growth and area scale for food production influenced food self-sufficiency and these critical issues need to be carefully considered for future actions.

In Sabah, the issue is about how to secure food in a sustainable manner with some pressures such as population growth, conversion of a large scale food production land into housing and plantation industry areas. It might be nice to improve productivity by utilizing modern technology. More importantly, however, land for food production should be secured and protected for food security in a long term. Protected areas for food production and food supply are a minimum requirement to accommodate human needs. Sabah has three big cities namely, Kota Kinabalu, Sandakan and Tawau which are consuming a significant amount of food. Such cities depend on rural areas in northern and western parts in Sabah for food supply. It might be possible to consider whether Sabah's food security should be based on basic domestic self-sufficiency or it should be substituted by import (Shutao 2010). Though this needs to be further discussed especially at the political level, recognizing that rural areas in the northern and western parts in Sabah still have the potential to produce surplus food, it is important to establish a linkage between the city and rural areas. Rural areas can provide people in the city with food and a place for doing agricultural activities for their self-consumption. On the other hand, city areas can provide people in the rural areas, particularly farmers with

technical and financial support for sustainable food production. In addition, the linkage between city and rural area can be a potential for realizing a material recycling society through making composts in the rural area, and producing renewable energy by using food such as rice husk and coconut shell. As the case in Japan indicates (Sato, 2012), this kind of linkage and partnership between two areas can serve as a basis for food-related business such as eco-tourism, thereby making the self-sufficiency of food more stable. Lastly, Sabah is still suffering from poverty, especially in the rural area (poverty rate in 2012 is around 8 % according to the Department of Statistics of Malaysia, 2014). City-rural partnership for improving food security could contribute to poverty alleviation.

3.2.4 Conclusion

It has been pointed out that food production is influenced by the combined effects such as population growth, nutrition transition, energy, water, climate change and so on. This research focused on energy based food self-sufficiency ratio in Sabah. It can be concluded that the situation on energy based on the self-sufficiency of food in Sabah should not be optimistic, but rather a critical situation. This research can visualize the situation on energy based self-sufficiency food ratio in Sabah by utilizing available data, and provide reliable and persuadable Figures for future actions. This research is the first of its kind, and hopefully can contribute to relevant policy development and compliment other food-related researches in the future.

Session 3.3 Analysis of energy consumption and biomass energy potential at Tudan village

3.3.1 Introduction

As evaluated in Session 3.1, Sabah has significant biomass energy potential. In session 3.1 discussed use of biomass energy in the regional context to develop a new industry which might create new job opportunities, thereby activating the regional economy and helping to alleviate poverty. Here, in order to understand local situation in details, energy consumption structure and biomass energy potential at local level were analyzed. Tudan village was selected as a pilot site for this purpose.

47 percent of all communities at Tudan village own at least a single motorized vehicle which is an important asset to transport agricultural products from the farm to markets, as well as to travel out of the village as there are no public transportation services available. Private vehicles are also important to send and pick-up children from boarding schools during the weekends and the longer school holiday break.

More than 44% of communities own basic agriculture implements such as chainsaws and grass cutters, as well as plough machines (23.5%). However, in most cases, agriculture production is still carried out by using basic tools. Tudan village received electricity supply only recently in 2013. Today, with stable electricity supply from the main grid, the ownership of electrical goods is common.

More than 61% of communities in Tudan village own at least one television set, and more than 40% of communities own kitchen appliances such as refrigerators and rice cookers. Of interest also is the growing number of communities who now own a

desktop or laptop personal computer. Some communities still own electricity generators which was used before houses were connected to electricity grids.

3.3.2 Result

As explained in ‘2.2.3.2 Data analysis and calculation’, energy consumption structure and potential biomass energy are summarized as Table 3.4 and Table 3.5.

	MJ/year/HH
Electricity	3,026
Gas	2,413
Gasoline	24,348
Diesel	9,564
Firewood	8,943
Total	48,294

Table 3.4 Energy Consumption at Tudan village

	MJ/year/HH
Forest	3,693
Livestock waste (fecal pellet of pig)	30,660
Rice husk	1,575
Total	35,928

Table 3.5 Potential biomass energy at Tudan village

It was revealed that around 50 % of total energy consumption in the village came from gasoline. It was because Tudan village has no public transportation facilities, so people need to go to the town to purchase daily goods, visit the hospital and transact business at the local government office by means of their own cars. Notably, the development of access roads to cities such as Kota Kinabalu resulted in an increase in the use of cars, and therefore the consumption of more gasoline. Therefore, portion of

gasoline amount used out of total energy consumption was high. On the contrary, it was also found that Tudan had a huge potential of biomass energy derived from forest, livestock waste and rice, which covered around 74 % of total energy consumption. This indicates that Tudan village has the potential for building a self-standing structure in terms of energy.

At the moment, the utility rate of electricity at Tudan is 11RM~17 RM per month per household on average (1RM: Malaysian Ringgit $\doteq$ 0.24USD, as of October, 2015). Sabah State government has had supporting-schemes for communities. If the utility rate is less than 20 RM, the government waives the collection of fees for electricity. This scheme, to some extent, can help to curb the overuse of electricity. It is not guaranteed, however, this government scheme will be continued in the future.

Usage of firewood for cooking has been very common in Tudan village. Though the community needs to go to the forest area which is far from the residential area and located in a hilly place, community members prefer meals such as rice cooked by firewood rather than by using gas. Certainly, gas has been become common in the village, but it is probable that the usage of firewood will remain constant for the time being and be one of the most important energy sources for the community's daily life.

3.3.3 Discussion

Although most communities now engage in the planting of cash crops, subsistence agriculture remains as an integral part of the livelihood of the Tudan village. Subsistence crops have traditionally been planted for generations and still provide a form of food security for families whose incomes from cash crops are sometimes uncertain. In the meantime, communities now more readily purchase a variety of food

products from outside with income generated from cash crops and due to the ease to access to markets in the urban area. This might accelerate use of gasoline in future and there might be a growing dependence on food and energy coming from outside. Challenge Tudan village in terms of food security and energy resources use is facing now is how it can become independent by effectively utilizing potential of biomass energy in the village.

3.3.4 Conclusion

In conclusion, a half of the energy usage at Tudan village comes from gasoline. Though a governmental scheme has been functioning as an incentive which encourages community members not to excessively use electricity, easy access to a big city and neighboring towns for marketing local products such as vegetables and for purchasing daily groceries coupled with ‘no-public transportation or local hospital’ results in the village having an increase in gasoline usage. In the meantime, Tudan village has a huge potential of biomass energy. It might be possible to consider how to utilize biomass energy available in Tudan village to reduce the usage petroleum such as gasoline. Furthermore, innovative biomass-based technologies could be developed in future at Tudan village.

Session 3.4 Analysis of Social Capital (Happiness degree) at Tudan village

3.4.1 Introduction

The Satoyama Agricultural Development Tool (SADT) developed by Dublin and Tanaka (2014a) was applied in the village of Sabah State, Malaysia, and then a questionnaire survey, what is referred to as “Happiness Survey”, was conducted to evaluate from a more social point of view by adding another criteria. This study was conducted in Tudan Village, Tuaran District, Sabah State, Malaysia from May 2014 to February 2015. The research highlights issues to be carefully considered for designing the project and demonstrates the effectiveness of SADT and Happiness Survey as a diagnostic tool for evaluating a *Satoyama* System through formulating a Satoyama Project.

Happiness survey originated from case studies conducted in Japan which researched the degree of happiness of people affected by the Great earthquake and tsunami in 2011. As referred to in the title, the survey in this thesis was tailored for assessing the level of happiness degree of the community at Tudan Village. In fact, this survey focused on more social aspects of the people and the community. In this study, the questionnaire framework was developed with reference to previous studies in Japan and the Kingdom of Bhutan which is widely recognized as a happy state in the world and has some advanced studies to assess the level of happiness among its citizens. Furthermore, the ‘Rules of Village Consensus and Organized Plan of Village Development’ at Tobobon village which is a neighboring village of Tudan was referenced to reflect more of the locality. The questionnaire framework is shown in Table 3.6. By making references to

some case studies in Japan and Bhutan, and the rules and development plan at Tobobon Village, questions for measuring the degree of happiness can be grouped into eight categories in “Tudan Village in General” and five categories in “community’s behavior and awareness”. Each question item provides 4-levels of options for choice, and a rating from 1 to 4 brings the level of satisfaction to light, and eventually assesses the total level of happiness. Open-ended items were also included.

Table 3.6 Questionnaire framework

I. About Tudan Village In General

A	Natural Environment And Life Environment At Tudan Village
1	Life In Harmony With Nature
2	Conservation/Protection Of Rich Environment
3	Hygienic Conditions (Garbage Treatment)
4	Renewable Energy (Solar Panel etc.)
5	Water Supply
6	Sewerage Systems
7	Road Conditions
8	Information And Telecommunication Conditions
9	Housing Conditions
10	Public Facilities
11	Purchase Of Daily Commodities
12	Securement Of Means Of Daily Transportation
13	Land Ownership
B	Educational Environment At Tudan Village
1	Educational Environment At The Village Level
2	Educational Environment At School
C	Industry At Tudan Village
1	Agriculture
2	Forestry
3	Fishery/Aquaculture
4	Farming/Livestock
5	Local Production For Self/Local Consumption
6	Outside Market For Business
7	Tourism/Eco-Tourism
8	Job Opportunities
D	Preservation And Inheritance Of History/Culture At Tudan Village
1	Medical Service In Case Of Illness And Injury
2	Welfare Service For Elderly People
3	Precaution For Illness Such As Health Consultation, Guidance And Health Check

E	Preservation And Inheritance Of History/Culture At Tudan Village (Satisfaction/Dissatisfaction)
1	Preservation And Inheritance Of Local Food And Local Food Culture
2	Preservation And Inheritance Of Local Custom, Law, Rule, Wisdom, Legend And Knowledge
3	Preservation And Inheritance Of Landscape
F	Circumstance Of Life At Tudan Village
1	Measures For Security, Safety And Crime
2	Measures In Case Of Disaster
3	Fire-Fighting Community And Patrolling For Security/Safety
4	Environment For Child-Raising/Nurturing
5	Leisure
6	Place Where Elderly People Live Safely
G	Community Empowerment At Tudan Village
1	Community Meetings And Community Activities
2	Support For Each Other In Times Of Need
3	Group Members And Friends In Times Of Need
4	Circumstances Where You Can Practice Your Knowledge And Skills
5	Communication With Outside (Human Exchange, Information Etc.)
H	Governance At Tudan Village
1	Community Needs In Reflection To Village Policy And Village Activities
2	Accountability Of Government
3	Access To Sources Of Necessary Information
4	Communication Between Government And Local Community
5	Community Development In A Participatory And An Initiative Way Of Local Community

II. About Community's Behavior and Awareness

I	Behavior
1	Environment-Conscious Life
2	Environment-Conscious Local Activities
3	Personal-Health Conscious Activities
4	Activities For Learning And Education
5	Participation In Local Activities
J	Food/Dietary Life
1	Procurement Of Safe Food And Preparation
2	Procurement Of Local Traditional Food And Preparation
K	Feeling
1	A Sense Of Solidarity/Togetherness As A Member Of The Community
2	A Sense Of Loneliness/Isolation In Daily Life
3	A Sense Of Anxiety/Uneasiness In Daily Life
L	Satisfaction In Daily Life
1	Health Condition
2	Daily Food
3	Balance Between Work And Life (Leisure)
4	Income (Household)
M	Happiness
1	Are You Happy Now?
2	Priority Criteria And Issue For Judging Happiness
3	What Is Your Image Of A "Happy Place" And "Happy Life"?
N	Wish/Knowledge About Village
1	Do You Feel Attachment And Familiarity To The Village?
2	Do You Know Local Goods/Products Of The Village?
3	Do You Know Local History And Cultural Resources Of The Village
4	Do You Want To Continuously Live In The Village?
5	Things You Are Proud Of The Village

Rating

Options	score
I'm satisfied, I'm active, I feel, I think so, I know	4
I'm rather/somewhat satisfied, I'm rather/somewhat active, I rather/somewhat feel, I rather think so, I know some	3
I'm rather/somewhat dissatisfied, I'm rather/somewhat inactive, I rather do not feel, I rather don't think so, I do not know many	2
I'm dissatisfied, I'm inactive, I do not feel, I do not think, I do not know at all	1

Note: Score of a sense of loneliness/isolation at K-2, and a sense of anxiety at K-3 are in reverse order from the above.

3.4.2 Result

1) Satoyama Diagnosis by SADT

As Dublin *et al.* (2014c) found, Tudan village was evaluated to be Satoyama Like.

Detailed results are shown in Table 3.7 (Details are shown in Appendix 4).

Cyclic use of Natural Resources			Resource Use based on Carrying Capacity and Resilience of Environment			Recognition of the Importance and Value of Local Cultures and Traditions			Collaborative Management of Natural Resources			Contribution to Local Socio-Economies			Final Evaluation		
PO/PP	%A	R	PO/PP	%A	R	PO/PP	%A	R	PO/PP	%A	R	PO/PP	%A	R	%A	SP	R
36/45	80	H	52/60	86.67	H	24/35	68.57	M	23/25	92	H	28/35	80	H	81.45	0.81	SL

PO/PP – Point Obtained of Possible points, %A – Percent of Answer Points obtained

R – Rating, SP – Satoyama Points, SL – Satoyama Like

H – High, M – Medium

Table 3.7 Results of Satoyama Evaluation of the communities studied (Dublin *et al.*, 2014)

Through the data collection process of the interview with a representative of the village, apart from arriving at a score from 1 to 5 by utilizing SADT, additional data which helped to sharpen the understanding of the village background was collected. This process could contribute to enhancing mutual communication between a researcher and an interviewee. As can be found from the Percent of Answer Points as shown in Table 3.7, Tudan village, of the five perspectives, only “Recognition of the Importance and Value of Local Cultures and Traditions”, obtained less than 80% (68.75%). The item related to tourism was the only one with 1 score. The Interviewee, the deputy head of village, confided that Tudan village did not have practices of eco-tourism, agro-tourism, nor homestays. However, some villagers are interested in environment–

based tourism, but they do not know how to begin or what should be done. Among the issues with low scores is waste management. Waste management is a crucial issue which needs to be urgently addressed. The village does not have a functioning waste management system. In fact, the households in the community dispose of their waste including plastic materials on their own in inappropriate ways.

2) Happiness Survey

(1) Identification of Significant items

After grading, all responses, identifying items which shows an outstanding feature in terms of the satisfaction level, averaging the actual observed data, and comparison with expectations; the results are shown in Table 3.8 (Raw data is shown in Appendix 5.1 and 5.2).

Table 3.8 Significant items

1) Items showing a high degree of satisfaction (difference between statistically expected value and actually observed value is more than 4.)		2) Items showing a high degree of dissatisfaction (difference between statistically expected value and actually observed value is less than 0.)	
Category	Question item	Category	Question item
A	life in harmony with nature	A	purchase of daily commodities
A	conservation/protection of a rich environment	A	securement of means of daily transportation
A	water supply	C	farming/livestock
B	educational environment at the village level	C	tourism/eco-tourism
B	educational environment at school	D	welfare service for elderly people
C	agriculture	F	measures in case of disaster
C	forestry	G	community meetings and community activities
G	support each other in times of need	K	a sense of loneliness/isolation in daily life
G	group member and friends in times of need		
I	environment-conscious local activities		
I	personal-health conscious activities		
J	procurement of safe food and preparation		
J	procurement of local traditional food and cook by using it		
L	health conditions		
L	daily food		
L	balance between work and life (leisure)		

Most of the respondents were satisfied with the natural environment of the village. Surrounded by pristine water and rich forest, people can live satisfactorily. However, as for daily life, the results showed that the community found difficulties in purchasing daily commodities and securing means of their daily transportation to have access to town or city. As stated in Dublin *et al.* (2014), Tudan community revealed that they would have purchased most of their daily groceries from outside of the village if they had a higher spending power. This shows that the low spending power actually allows them to consume healthy foods such as chemical-free food which is produced at the village level. It was found that the educational environment was satisfactory although Tudan only has a primary school, thus, junior high school and high school students need transportation to attend school. On the contrary, they may live in the neighboring town away from their family. Regarding industries at the village level, most of the respondents indicated that they were satisfied with agriculture and forestry. It can be easily understood that because agriculture was their major source of income, these traditional practices formed part of their own identity. It was also evident that the local community owes much of their livelihood to the existence of a rich forest. In contrast, livestock especially pigs and wild boars damage the community's agricultural land and the backyards of their houses. In regard to nature-based tourism such as eco-tourism and homestays, as was identified by the SADT, the Happiness Survey also found that the community was less satisfied though some residents were willing to begin, thus utilizing the benefits of the beautiful environment and local culture such as the local dances of the village. The incidence of natural disasters is one of the serious concerns for the community. Traditionally, the community has taken measures against landslides

and soil erosion caused by heavy rains by placing huge stones on the ground and planting bamboo. However, sometimes the disaster is beyond their control. Some say that the drainage system designed by the government contributes to disasters because the government paid no attention to the topographic features of the village. Therefore, it can be surmised that the community members are not satisfied with the public works performed by the government. Community empowerment corrects this anomaly. As indicated by the results, the community members help and take care of each other, especially in the face of natural disasters and serious illness in the village. This kind of social cohesion and ties among community members are based on their traditional customs, and serves as a basis for community empowerment and development. Against this background, some feel loneliness and isolation and it was revealed as a case especially among the elderly. And welfare service for elderly people was the issue. On the one hand, elderly people can transfer their knowledge to the younger generation and are actually willing to do so. However, the younger generation has difficulties to find job opportunities and educational enhancement at the village level. Therefore, they are eager to go to urban city centers such as Kota Kinabalu and even peninsula parts in Malaysia like Kuala Lumpur, becoming separated from their family in the process. This phenomenon is generated by economic globalization which affects communication between the two generations. Communication and socialization including community meetings and community activities between different generations are crucial for local knowledge preservation as well as community empowerment in the long term. Community members consider themselves as environmentally conscious people who always act in an environmentally friendly way. They are satisfied with their daily local food supply which comes from the healthy natural environment of the village. Partly

due to healthy food consumption, it is believed that people in the community live longer. The eldest living person is currently 101 years old (as of 2014). All community members are proud of this. At the stage of Happiness Survey, significant features with regards to health and wealth; culture and history of the village; and governance in the village cannot be easily appreciated.

(2) Gender Considerations

Noticeable differences between male and female in the respondents were found when the Exact Wilcoxon Test was applied. Results are shown in Table 3.9.

Table 3.9 Results of differences between male and female

p < 0.01

Category	Question item	Description of differences
C	Farming/Livestock	Most of males (83%) are less satisfied or not satisfied while most of females (86%) are very satisfied.
C	Job Opportunities	More than half of males (67%) are less satisfied or not satisfied while all females are very satisfied.
D	Medical Service In Case Of Illness And Injury	More than half of males(73%) are less or not satisfied while most of female(86%). are very satisfied or satisfied
D	Precaution For Illness Such As Health Consultation, Guidance And Health Check	Most of males (82%) are less or not satisfied while most of female (83%) are very satisfied.
G	Communication With Outside (Human Exchange, Information Etc.)	More than half of males (75%) are less satisfied while half of female(50%) are very satisfied.
H	Accountability Of Government	Most of males (92%) are less satisfied while more than half of female(71%). are very satisfied
H	Access To Sources Of Necessary Information	Most of males (83%) are less or not satisfied while most of female(86%). are very satisfied or satisfied
H	Communication Between Government And Local Community	Most of males (92%) are less satisfied while more than half of female (71%). are very satisfied
I	Activities For Learning And Education	More than half of males(58%) are less satisfied while most of females (86%). are very satisfied

$p < 0.05$

Category	Question item	Description of differences
A	Sewerage Systems	Half of males (50%) are less satisfied while most females (83%) are very satisfied.
A	Public Facilities	More than half of males (73%) are less satisfied or not satisfied while more than half of females (71%) are very satisfied.
A	Land Ownership	More than half of males (58%) are less satisfied while more than half of females (57%) are very satisfied.
B	Educational Environment At The Village Level	All females are very satisfied while not all male are very satisfied.
B	Educational Environment At School	All females are very satisfied while not all male are very satisfied.
C	Forestry	All females are very satisfied while not all male are very satisfied.
C	Fishery/Aquaculture	More than half of males (75%) are less satisfied or not satisfied while most of females (83%) are very satisfied
C	Tourism/Eco-Tourism	Most of males (92%) are less satisfied or not satisfied while most of female (80%) are very satisfied or satisfied.
D	Welfare Service For Elderly People	More than half of males (73%) are less or not satisfied while more than half of female (71%) are very satisfied or satisfied.
F	Fire-Fighting Community And Patrolling For Security/Safety	More than half of males (73%) are less or not satisfied while most of female (86%) are very satisfied.
I	Environment-Conscious Life	All females are very satisfied while not all males are very satisfied.
I	Personal-Health Conscious Activities	All females are very satisfied while not all males are very satisfied.

The results can be of use for identifying prioritized issues that needs to be urgently taken into consideration. Communication and negotiation with the outside, particularly with central and local governments are dealt with mostly by men. However, most of these men encounter difficulties communicating with the government. They feel that directions and instructions given by the government to the community in relation to agriculture and infrastructural development such as irrigation systems have been unclear or absent. Rural areas such as Tudan village is still categorized as “poor” in accordance with the standards set by the Sabah State government, thus Tudan village needs support from the government. Communication with the government cannot be ignored for community development.

Compared to women, men are seeking out opportunities for more income generation. Nowadays, unemployment is one of the big social problems in Sabah, and Tudan village is no different. Young men who graduated from high school in the neighboring town or Kota Kinabalu returns to Tudan after failing to find a job in the town or city.

One point highlighted here is the fact that men rather than women are anxious about health issues though the previous Happiness Survey showed no significant result associated with health. This might be worthwhile being explored during the project implementation. Overall, men’s territory is close to the village boundary for agriculture activities while women’s are mostly restricted to areas nearby to the housing. JICA conducted a community mapping session for the community. Map making is a useful tool to visualize the spatial and social organization of a community. A map that was made by the community allows for the visualization of the landscape the way the community members see themselves, often highlighting assets, resources, areas, institutions, and structures that are important to the community. Differences in

resource use between men and women were found through the community mapping works. Generally women collected resources in areas that were nearer to the homesteads while men would venture out further, for example, up to the boundaries of the forest protected area to extract large trees for timber to build houses. Thus, it was observed that women, whom mostly were housewives, tend to closely map out their activities closer or being in the neighborhood conducting farming and foraging for herbs and edible plants in closer proximity to their village; men were mapping out with a focus on the boundaries of the village which is their territory for natural resource use. In this light, men raised the issue of illegal hunting in the forest around the border.

(3) Open-ended Questions

Responses to “Open-ended questions” are summarized in Table 3.10.

1. Priority Criterion And Issue For Judging Happiness
Always to be open to each other
Increase more recreational and group gatherings
Good farm yields
Family ties
Sports and recreational activities
Unity and understanding among family and community
2. What Is Your Image Of A “Happy Place” And “Happy Life”?
Togetherness among community members
Being with family
Have understanding and tolerance within the community
Peace/peaceful area
Cool weather
Have interesting attractions such as waterfalls
Good infrastructure
3. Things You Are Proud Of In The Village
Farming and animal husbandry
Cool weather, preserved surroundings
Peaceful surroundings
Local fruit
Festivals such as Kaamatan (Harvest Festival) and Christmas Community Gathering
Unity among community members

Table 3.10 Summary of free description

Responses to the open-ended questions indicate that family ties, community cohesion, and understanding each other are important aspects for living happily. Peace and security in the village are also indispensable aspects to which high priority should be given.

3.4.3 Discussion

1) SADT

In agricultural terms, it has been recognized in general that Tudan village was a “chemical-free” or “chemical less” village in agriculture. It was discovered through interviews, however, that a few community members utilized herbicides and pesticides at the land preparation stages to speed up the scouring of weeds and to kill pests. This suggests that the SADT is not only a method or tool to analyze the degree of Satoyama but is also a useful tool to register aspects that may be present in spite of the evaluation obtained. This is very important in terms of consideration of potential activities such as awareness programs. Traditionally the Dusun community has been practicing diversified agriculture in Sabah. This was inherited from their ancestors for nearly 100 years or more. They fully understood through this traditional knowledge (TK) that agriculture with diversified crops could increase production rather than monoculture cultivation, and that it helps to enhance resilience against pests. When it comes to TK, the Tudan community selectively planted bamboo to curb soil erosion. This knowledge was traditionally handed down through generations. According to the interviewee, the awareness level of the community in relation to the environment was relatively high as they are proud of pristine water, fresh air, and an abundance of forest in the village environs. Also, they recognized that the area surrounding the village comprises of the Sabah national park and forest protected areas. This indicated that they also recognized the ecosystem linkages between the protected areas and the village territory. In social aspects, it was found that the amount of alcoholic intake was high in the village. This in itself was not recognized as a problem but as a social culture. Most villagers enjoy

social communication with each other while consuming beer and local rice wine.

Through the interview process by utilizing the SADT, the village profile from the perspective of the five Satoyama principles can be visualized. As stated above, this is a strong merit of utilization of SADT as a diagnostic tool. We can easily identify a series of issues to pay attention to, for example, waste management, and nature-based tourism; and also issues to be strengthened, for example, “less chemical” traditional-based agriculture, and environmental protection. In the case of Tudan village, as Table 3.7 and Appendix 4 shows, the village has sufficient elements to meet the criteria to be qualified as “Satoyama like” although some issues persist. In terms of project designing or prioritization of possible activities for a Satoyama Project, it can be reiterated that SADT may not be a stand alone tool.

In the meanwhile, two questions have arisen. Firstly, is an individual interview enough for collecting information by SADT to identify significant features and issues to be improved even if the interviewee is a representative of the village? Secondly, do we need more subjective views of interaction between human and nature?

Responding to the first question, Dublin *et al.* (2015) has already studied and produced results showing uniformity amongst villagers and amongst officers in three Karen villages in Chiang Mai, Thailand. It was found through his past studies that no statistical differences existed when analysis between officers and villagers were compared, demonstrating that if persons are exposed to the same data and experiences within a given locale, they would produce similar evaluations when using SADT. As for the second question, scoring Satoyama points by SADT is rather based on objective observation by the interviewee, and results are descriptive and show the level of “agreement” on the village environment. Presumably, since most of the questions set by

SADT began with “Is there? ~ or Are there? ~”, relatively objective observation for the current situation of the village was attributed to these types of questions. Ideally, more information with a focus on harmony between human well-being and nature conservation is needed to design the Satoyama Project because Satoyama is, repeatedly speaking, a village or community which is built on human-interaction with nature. In this sense, the village should be assessed from the perspectives of human-nature interactions. Considering these short discussions above, the method to assess the level of interaction between human and nature which was introduced and applied as “Happiness Survey” would now be assessed.

2) Happiness Survey:

To the question “Are you happy now?”, all gave the answer of “Fully happy” or “partially happy”. No one selected “ Less happy” or “Not happy”. Everyone is entitled to define happiness for themselves. The happiness survey produced persuasive results to evaluate the status of human-nature interaction by identifying distinguishing characteristics. The survey only represents 6% of the community (n= 19: Female 7, Male 12). It is desirable to conduct more studies with a higher number of respondents. More in-depth survey with comparison between younger and elderly generation should be considered. It should be noted however, that all respondents were representative of the village and are socially active villagers such as the village head, leader of the agricultural group, and the school teacher. The survey assisted in understanding the general trend of community perspectives on their satisfactions and dissatisfactions. Items that need to be prioritized in the future can be successfully identified. These are summarized in Table 3.11.

Recognizing that an appropriately protected environment is the base for future development at Tudan village, it is definitely important to use natural resources (forest, water, soil, etc.) for village development in a sustainable manner. In the meantime, since Tudan village is located in a remote area, the purchase of daily commodities and securement of means of daily transportation to have access to the city and town nearby are pressing needs. The more Tudan village relies on urban areas due to the expansion of the economic market, the more such needs will be amplified. From the viewpoint of village development, eco-tourism might be a potential for constant income generation if it can be designed and carried out in an environmentally sustainable manner. Priority should be given to development for a society where local customs and culture including local language can be preserved and conveyed to future generations. In addition, it was pointed out that the measurement for disaster was crucial because the village is located in a mountainous area and might be easily affected by natural disasters. It was also found that solidarity and cohesion; support for each other in times of need; and close daily communication among communities are critical issues to ensure that community members do not feel loneliness, isolation, anxiety, or uneasiness. Especially, care for the elderly people, including medical and welfare services should be taken into consideration. Moreover, communication between the government and local community should be promoted, and community-based transparent and accountable governance system should be developed. Differences between the perspectives of men and women presented in Table 3.9 should be taken into account for developing Satoyama projects. For example, communication with government should be enhanced by the project with a focus on men as the main target group. The results of open-ended questions reaffirmed that cohesion and solidarity among communities had substantial influences on the

feelings of happiness. At the same time, a clean and cool environment, and peaceful village are also important for feeling happiness.

3.4.4 Conclusion

This study demonstrated the effectiveness of the complementary application of two different tools, namely SADT and Happiness Survey to identify prioritized activities, and issues that need to be carefully considered in formulating a Satoyama Project for evaluating a Satoyama System. A Satoyama project ultimately aims at realizing a society in harmony with nature, and for the purpose of achieving this ultimate goal, this study provides a clue on how to make use of the strengths of each tool. Table 3.11 shows a summary of the issues which was obtained by the two tools to be addressed.

	SADT	Happiness Survey
Issues to be sustained	• Clean environment • Traditional agriculture	• Clean environment • Traditional agriculture • Education • Solidarity and cohesion among communities • Support for each other • Peaceful life
Issues to be considered/improved	• Eco-tourism and homestay • Waste management	• Purchase of daily goods • Access to town and city • Eco-tourism • Disaster (land slide) • Livestock • A sense of loneliness and isolation • Communication with government • Job opportunities (younger men generation) • Health (men) • Illegal hunting (men)

Table 3.11 Summary of the issues to be addressed

Issues identified by SADT can also be identified by the Happiness Survey. Some issues such as a sense of loneliness and isolation, and communication with government, to name a few were not identified by the SADT. This indicates a strong feature of Happiness Survey as a complementary tool with the SADT.

Through this study, the effectiveness of the complimentary use of SADT and Happiness Survey was demonstrated as an entry point and baseline survey for project designing in the context of Satoyama system evaluation. The sketch below in Figure 3.4 shows the overall picture of the approach taken by this research. Dublin *et al.* (2014) conducted a verification of the effectiveness of the SADT through a variety of world-wide case studies. Complimentary Happiness Survey was the first case in Sabah. This study can provide forward-looking assessment for the identification of several aspects to be taken into consideration in the future. Because of the wide definitions of happiness, it might be debatable if the question ‘Are You Happy Now?’ should be included. Perhaps the meaning and concept of Happiness should be developed through a considerable degree of community consensus at first. To say the least, sampling number is not enough to fully understand the interaction between nature and human. Differences between older and younger generations might be useful for identifying priorities. Considering these, happiness survey should be modified and improved through more practical case studies.

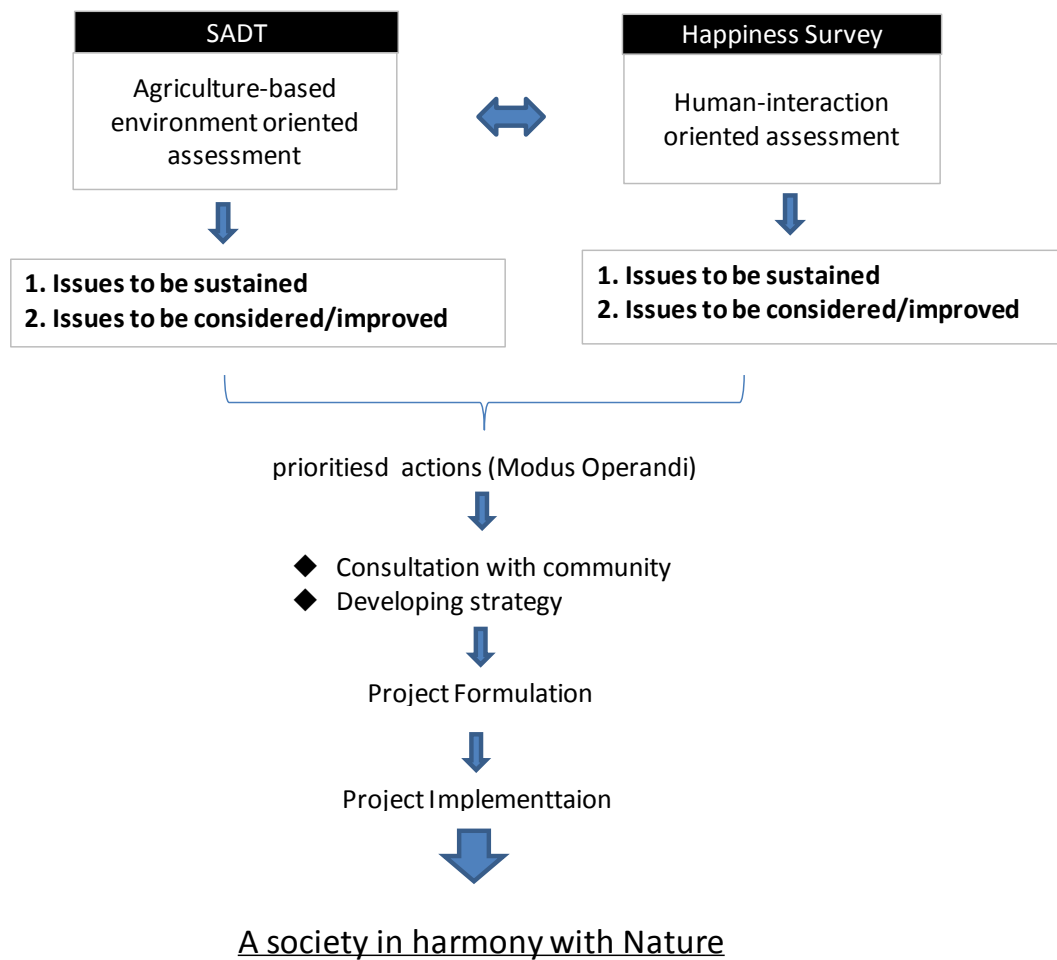


Figure 3.4 Overall picture of the approach and the results

Session 3.5 Analysis of Natural Capital at Tudan village

3.5.1 Introduction

The Millennium Ecosystem Assessment initiated by the UN from 2001 to 2005 indicated that ecosystem services on the earth had deteriorated on a larger scale irreversibly. It has been recognized that the restoration of ecosystem services was indispensable for the conservation of valuable nature and the improvement of human-wellbeing. Thus, international communities agreed on the occasion of CBD COP10 (2010, Japan) that the restoration and protection of ecosystem services were absolutely necessary for achieving the millennium development goal (MDG).

In the meantime, the first Earth Summit in Rio de Janeiro in 1992 focused on the natural environment and the services it provides (collectively, Earth's "Natural Capital") in sustaining human existence. The Natural Capital Declaration says that Natural Capital comprises Earth's natural assets (soil, air, water, flora and fauna), and the ecosystem services resulting from them, which make human life possible. Ecosystems goods and services from Natural Capital constitute food, fiber, water, health energy, climate security and other essential services for human-wellbeing. Neither these services, nor the stock of Natural Capital that provides them, are adequately valued compared to social and financial capital. Therefore, compared to other sectors and fields such as infrastructure buildings, natural conservation or biodiversity conservation is not a priority on the political agenda in many countries in the world. Thus, it is necessary to value Natural Capital in a quantitative manner as much as possible and visualize it to for putting a priority on natural conservation or biodiversity conservation. This is referred to as mainstreaming of natural conservation or biodiversity conservation in the context

of development. Economic value of Natural Capital needs to be fully recognized, and such value should be treated as one of the important components in policy implementation, and not be as an external diseconomy (like environmental pollution). Natural Capital should be positioned at the same level as social and financial capitals to ensure that maintenance and enhancement of Natural Capital should be clearly stated as the important priority issues in development policy.

Local community members of Tudan village depend on Natural Capital for their daily life. This indicates that restoring and protecting Natural Capital are needed for livelihood improvement in the village and can lead to poverty alleviation.

This session presents the result of analysis of Natural Capital in Tudan village and assessed the value of Natural Capital.

3.5.2 Result

Table 3.12 below shows the result of economic value of Natural Capital at Tudan village.

Natural Capital		Economic Value per year (unit: RM)
1. Public interest functions of forests		
Fossil fuel substitution effect by using biomass		115,500
Function for flood mitigation		28,679,940
Function for water storage		99,087,597
Sub-total: 128 Million RM(3,709 Million Japanese Yen)		
2. Public interest functions of agricultural land		
Global warming effect by gas emission (methane emission by livestock feeding)		3,459
Function for flood prevention		2,307,569
Function for soil erosion prevention		130,000
Sub-total: 2.4 Million RM (71 Million Japanese Yen)		
Total: 130 Million RM (3,800 Million Japanese Yen)		
(1RM: Malaysian Ringgit ÷ 29 Japanese Yen as of December 6, 2015)		
3. Others		
Fossil fuel substitution effect by building a house		297,000RM (8,602,000 Japanese Yen) (Note: this is not capital per year. Refer to explanation below.)

Table 3.12 Summary of Natural Capital value at Tudan village

1) Public interest functions of forests

1.1) Fossil fuel substitution effect by using biomass

Wood mass is cheaper than fossil fuel and using wood mass helps to reduce the cost. Moreover, if such wood mass can be produced within the village, financial capital which often goes to the town and city outside the village can be cycled intraregionally, which contributes to energy security in the village. Tudan communities use fire wood on a daily basis, and its amount is around 3.5kg/day/household. This is equivalent to 45,990 kg/year/village and around 55m³/year/village by applying 0.83 tonne/m³ in case of broad-leaf tree with 30% moisture content (Japan wood energy Co.,Ltd.). Given that gasoline is the biggest among others such as gas and diesel in terms of energy consumption in the village as analyzed in the Section 3.3, translating this into gasoline terms, this figure is equivalent to 55,000 Liters (gasoline) and this is worth **115,500RM/year.**

1.2) Function for flood mitigation

Forests have the function to control and prevent floods. Data on rainfall intensity (124.07 mm/h) at Kota Kinabalu was obtained from the Meteorology office at Kota Kinabalu (no data on rainfall intensity at Tudan village were available.). Runoff factor (0.3), and forest area (189.90 ha) were applied to calculate flow equalization amount, 20m³/s (0.1899 thousand ha × 124.07 mm/h × 0.3 × 1,000/360). Annual depreciation cost and annual maintenance cost of the dams in Sabah are 1,419,799 RM/m³/s and 14,198 RM/m³/s, respectively (Hasegawa). Thus, the function of flood mitigation was valued as **28,679,940 RM** (20m³/s × (1,419,799 RM/m³/s + 14,198 RM/m³/s).

1.3) Function for water storage

Developed forest soil has a thick layer with an infinite number of small loopholes. Thus, forests have the function of water storage by impregnating water into these loopholes.

Storage volume at the watershed area needs to be calculated at first. This volume (m^3/year) can be derived from the applying the formula of forest area ($1,899,000\text{m}^2$) $\times$ annual rain fall ($2,250\text{mm}$) $\times$ storage rate (0.51) equals $2,179,102,500 \text{ m}^3/\text{year}$ (storage rate 0.51 is the case in Japan because such Figure in Sabah cannot be found.). This is $69.10 \text{ m}^3/\text{second}$. Then, considering the annual depreciation cost and annual maintenance cost of dam in Sabah ($1,433,997\text{RM}/\text{m}^3/\text{second}/\text{year}$), function for water storage was valued as **99,087,597RM**.

2) Public interest functions of agricultural land

2.1) Global warming effect by gas emission (methane emission by livestock feeding)

Livestock chews the cud and produces methane gas. In the case of Tudan village, pigs are reared. There are chickens in the village as well, but they have a very small degree of methane gas production. The village does not have cows. Considering the number of pigs in the village, methane gas emission factor and global warming potential are 720 pigs, 0.0011 (tonne methane gas per pig) and 21 respectively, methane gas emission from pigs are calculated as $16.632 \text{ tonne} \times \text{carbon dioxide}$. Then, by using 6,046 Japanese Yen ($\div 208\text{RM}$) as a recovery cost of one tonne of carbon dioxide, methane emission by livestock feeding can be valued as around **3,459RM**.

2.2) Function for flood prevention

Soils in the field temporarily pool rainfall, and gradually drain water downstream. This function helps to prevent and mitigate flooding. Tudan village has 260.59 ha of farm land. In order to calculate effective storage capacity, 0.2m of plow thick layer and 0.2 % of effective pore ratio are used. Then, effective storage capacity of farm land in Tudan village was $104,236 \text{ m}^3$ ($260.59 \times 10,000 \text{ m}^2 \times 0.2\text{m} \times 0.2$). As for annual depreciation cost and annual maintenance cost of dam in Sabah per effective storage capacity, those data cannot be found in Sabah. Therefore, data available in Japan, namely 636 Japanese Yen / m^3 and 6 Japanese Yen/ m^3 , respectively were used here. Then, the function for flood prevention by agricultural land can be valued as 66,919,512 Japanese Yen ($104,236 \text{ m}^3 \times (636+6)$), which is equivalent to **2,307,569 RM**.

2.3) Function for soil erosion prevention

In general, Sabah is prone to land slides especially in the rainy season. Many were caused by human-induced activities such as tree-cutting in the hill sides. Areas around Tudan village suffer from a big landslide and flooding twice a year (June and December) on average. Heavy rain affects agriculture and sometimes leads to loss or damage of equipment. The cost is estimated as 2,000 ~ 3,000 RM per occasion. As a counter-measure against heavy rains, community members at Tudan village purposely make contour planting of bamboo to avoid soil erosion (photo 3.1). Another measure is to put stones in the farming land to make terraced fields for the purpose of avoiding soil erosion through mitigating water flow (photo 3.2). Nevertheless, in the case of heavy rains, effects by flooding are beyond the control of community members. The worst

flooding occurred in June, 2014. At that time, according to community members and the local government, the cost for repairing infrastructure was approximately 200,000RM, and 10,000 RM for damage to agricultural products and equipment at Tudan village. Normally, except for the unexpected case above, Tudan village suffers little or no damage of infrastructure due to their traditional practices which reduces soil erosion and landslides. It usually costs between 50,000~80,000 RM per flooding event to repair damaged infrastructure. Therefore, the function for soil erosion prevention by local traditional practices can be valued at approximately **130,000 RM** per year (averaging 50,000~80,000 RM to 65,000 RM and considering two flooding events a year).



Photo 3.1 Circle highlighted in red shows bamboo plantation area

(photo credit: Kazunobu Suzuki)



Photo 3.2 Terraced field (photo credit: Kazunobu Suzuki)

3) Fossil fuel substitution effect by building a house

Materials used for construction creates carbon emissions during the process of being produced such as lumber and reinforced concrete, and iron frame. Houses which use materials with less carbon contribute to a reduction of carbon dioxide emission. Table 3.13 shows the types of housing materials used at Tudan Village. Tudan village has no houses made by reinforced concrete and iron frame which can be seen in Tudan's neighboring towns and Kota Kinabalu city. In this regard, the housing situation in Tudan is environmentally friendly.

Table 3.13 Type of Housing Material

No.	Type of Material	No. of Houses
1.	Wood and bamboo	6
2.	Wood	13
3.	Wood and brick*	8
4.	Brick	6
5.	Not specified	2

* Ratio between Wood and Brick is 70% : 30% respectively

Carbon emissions during the manufacturing of housing materials were evaluated. Firstly, assuming that all housing at the village except for those in the 'Not specified' category in Table 3.13 was made by reinforced concrete, carbon emission during manufacturing housing material was calculated. Here, the number of houses 33 and Floor area 90m²/house (6m × 7.5m × 2 floors), 21,814kg × Carbon (per house/carbon in case of 136m² floor area) were applied (SHIMOKAWA Research Institute for Forest

and Future Society). Then, 476 tonnes $\times$ Carbon was derived. This is equivalent to 1,745 tonnes $\times$ carbon dioxide (476 tonnes $\times$ Carbon $\times$ 44/12).

Secondly, the case of housing made from wood and bamboo was studied. Considering the ratio between Wood and Brick is 70% : 30% respectively, number of housing made from wood or bamboo is 24.6 (6+13+8 $\times$ 70%). And 5,140kg $\times$ Carbon (per house/carbon in case of 136m² floor area) was applied (SHIMOKAWA Research Institute for Forest and Future Society). Then, 84 Tonnes $\times$ Carbon was derived. This is equivalent to 308 tonne $\times$ carbon dioxide (84 Tonnes $\times$ Carbon $\times$ 44/12).

Lastly, the case of houses made from bricks was studied. Number of houses made from bricks can be calculated as 8.4 (6+8 $\times$ 30%). It was found that bricks used in the village was brought from Sandakan (western part of Sabah) and was made from Palm kernel shells derived from the oil palm. In this case, the conversion factor of carbon emissions per house/carbon in the case of 136m² floor area cannot be found in the reports and documentations available. Instead, it can be referred that one tonne of shell produces 2,203kg carbon dioxide (Laurence, 2012). At Tudan, around 800 bricks are needed for one house, and considering that 1 brick is approximately 3kg, bricks to build one house is 2,400kg. Thus, in total in the village, 20,160kg (2,400 $\times$ 8.4) of bricks are needed. Around 250kg of shell is needed to make one tonne of brick. Considering the above, around 11,103kg (11 tonnes) of carbon dioxide emission was assumed to have produced during the process of making bricks from shells.

From the calculation above, houses made from wood or bamboo and brick help to save emissions of 1,426 tonnes $\times$ carbon dioxide (1,745 - 308 - 11). By using 6,046 Japanese Yen ($\doteq$ 208 RM) as a recovery cost of one tonne of carbon dioxide, fossil fuel

substitution effect can be valued around **296,608RM**. This figure indicates the contribution to the reduction of carbon dioxide derived from the actual present housing situation (no houses made from reinforced concrete) in Tudan village in comparison with the assumption that all houses at Tudan village are built from reinforced concrete.

3.5.3 Discussions

Some Natural Capitals can be translated into monetary terms as stated above. On the contrary, some capitals cannot be done because of insufficient data and information. Though it is difficult to calculate economic value, some Natural Capitals which have the potential to be carefully studied and enhanced in the future are highlighted as follows.

Tudan village has around 189.90ha of forest and dominant tree species including *Dipterocarpaceae* (primary forest) and *Theaceae* (secondary forest). Though data to calculate the economic value of such trees are not available, there is no doubt that forests in the village have the function of carbon dioxide absorption. Apart from carbon dioxide absorption, the village has a huge potential of Natural Capital related to forests. Old growth forests can be found in a number of areas, some of which have been under long fallow from 20 years to as long as 50 years because the land owners have relocated outside the village. Land ownership, however, is still respected among the community members, and they engage in discussion with owners to preserve the forest as a community forest through the provision of incentives to the owners such as monetary compensations and international certification framework like FSC (Forest Stewardship Council). Such community forests can be managed sustainably by the village for the harvesting of forest resources as well as for complimentary activities such as eco-tourism and eco-based education.

Natural Capital in relation to biodiversity cannot be valued at this moment as data and information necessary for calculation are not enough. Tudan village, however, has potentially a variety of biodiversity-related Natural Capital. One of them is presence of traditional herbal plants in the village. Community members have been using some herbal plants to reduce ailment such as stomachache and insect bites, cure fever and diarrhea, and to treat eye infection, to name a few. These functions of herbal plants might have a huge potential to explore business opportunities in the future. Recreational and cultural functions also are future potentials to be explored. At this stage, Tudan village has no basis to start eco-business including eco-tourism and agro-tourism, and eco-education by making use of natural capital. Natural Capital at Tudan village also has the potential for developing eco-based partnerships between the village and neighboring towns or cities in the region. It is expected that Tudan village will attract tourists and will provide them with locations to implement environment education and social activities.

It is possible that traditional agriculture practice at Tudan village can enhance Natural Capital. Swidden agriculture has been practiced traditionally at Tudan. The term 'swidden' agriculture is synonymous with other terms such as 'slash-and-burn' or 'shifting' agriculture. Local farmers at Tudan had practiced swidden agriculture for generations, and had been protecting the pristine environment. At Tudan village, basically agriculture has been practiced in a limited land space due to steep slopes and shallow soils. But the traditional knowledge-based agriculture has not been exhausting the land, and rather, farmers have effectively used such limited land with less impact on the soil and environment. According to farmers, black or blackish colored soil was an indication of the best soil fertility. They can identify soil with black or blackish color as

good soil for farming, and selectively do swidden agriculture. A new study was reported that the native peoples of Brazil have improved the poor Amazonian soil, using bio char (applying low quality charcoal to the soil) to make terra preta soil, a fertile black soil, and at the same time, achieved remarkable improvements in the soil's carbon storage (unlike organic matter charcoal decomposes with difficulty) , and improved the biomass production (Lehmann *et al.*, 2006) . From Japan, it has been reported that with accumulated andosols (“an” means dark and “do” means soil, which are soils found in volcanic areas formed in volcanic tephra.), charred plants contributed to the generation of Type A humic acids and fulvic acid as well as increasing the soil's carbon storage (Miyazaki *et al.*, 2006). It has been recognized that Bio char functions, other than the increase of soil fertility, includes the increase of carbon sequestration, reduction of CH₄ Emission, Reduction of Chemical Fertilizer (this means reduction and CO₂ Emission), increase of water holding capacity and increase of air permeability. This illuminates the great importance of the *Satoyama* System as a measure for alleviating climate change. Considering the above, the argument that swidden agriculture was not good for the environment was still open for discussion and needed to be studied both from the scientific (laboratory analysis) and traditional knowledge points of view (Suzuki *et al.* 2015) .

As for the carbon storage function, bio char use is one of the promising practices. On a trial basis at Tudan village, bio char was made by community members from bamboo which was abundant. It was observed that vegetables in the farm land can grow faster with bio char. Though it is of course that more studies and researches on the function of bio char should be done, bio char might be good in terms of both carbon storage and improvement of agricultural production.

Application of chemical fertilizers helps to promote global warming. It is well known that during the process of converting ammonia in the fertilizer into nitric acid, and during the process of converting nitric acid into nitrogen gas, nitrous oxide is released in the air. This nitrous oxide contributes to global warming. In terms of curbing global warming, it is desirable not to use chemical fertilizers to the extent possible. Tudan has been practicing traditional agriculture with less chemical fertilizers.

Function of organic waste disposal can be regarded as Natural Capital. Tudan village has tested the use of kitchen waste as compost. Composting by utilizing not only kitchen waste but kitchen oil and waste from livestock can enhance Natural Capital in the village.

Agricultural production is one of the Natural Capitals. Most of the agricultural products are for self-consumption within the village while some are sold outside the village such as the open market. Cash income from local vegetables is around 400 RM/household/month. As cash crops become more important, communities at Tudan village are now transitioning from subsistence into cash economies. If Tudan village can produce surplus products, this amount will be larger. Apart from this, two alternatives of livelihood improvement at Tudan village are highlighted. One is bee-keeping (apiculture). Bee-keeping was one of the traditional agriculture at Tudan. During the 1990's, El Niño-associated climatic anomalies happened at Tudan village. As a result, bees migrated from the village. Due to the clean environment at Tudan village, however, bees have recently returned to the village, and the community made efforts to revive their traditional bee-keeping. At the moment (as of April, 2015), honey production was around 345kg/year and the market price of this volume is equivalent to 28,665 RM/year. The other is mulberry production. At Tudan village mulberry was planted for the first

time by an active farmer. Mulberry at Tudan village is *Morus alba*. As of April, 2015, a number of planted mulberry within the village was 308 trees. The production scale was around 60kg in 2014, and the market price of this volume was 2,000 RM. Some communities have been working hard to increase cash income from these alternative products. Frankly, but as a matter of fact, some food goods in the marketplace including honey and fruit-jam contains chemicals and substandard materials. And in some cases, the mandated product information is absent from the product label. In this sense, Tudan has a great potential to explore market opportunities by making use of the advantage of chemical-free or less-chemical products. UNESCO MAB brand can possibly add value to Tudan's local products.

3.5.4 Conclusion

It can be concluded that Tudan village has significant value of Natural Capital though some cannot be easily translated into economic terms. It is possible, however, to visualize such potential capital to have meaningful value in the future if efforts to enhance Natural Capital are made. Natural capital is one of the important components for establishing an integrated *Satoyama* System at the village level. The evaluation of Natural Capital at Tudan village was done for the first time, and policy actions for maintaining and enhancing Natural Capital through supporting local community members will hopefully be taken in the future.

Chapter 4 General Discussion

This chapter discusses the future perspectives for a sustainable society based on the results presented in this thesis.

4.1 Design of New Society based on Rural-urban Partnership Structure

The United Nations reported that more than half of the world's population lives in urban areas, a proportion that is expected to increase to 66 per cent by 2050 (United Nations, 2015). It is urgently needed to enhance the capacity and sustainability of urban areas to accommodate the growing population. People in urban areas depend on various types of natural resources, natural capitals and ecosystem services provided by the surrounding rural areas. Thus, it is recognized that to sustain the urban system, rural-urban interrelation is one of key factors to consider. Also to establish urban sustainability, human-beings, especially those in urban areas, have to re-consider their mindset and life styles which are based on mass production, mass consumption and mass disposal, which often leads to global environmental disasters, such as climate change, air, land, and sea pollution, and land degradation.

To propose a new society design based on the urban-rural partnership structure, this thesis focuses on Tudan village of Sabah, Malaysia which possesses a huge potential of biomass energy and traditional and natural agriculture system, and usage of organic matter. In this thesis, a self-sufficient structure for regional partnership, namely urban-rural partnership regarding biomass energy and food was proposed. A self-sufficient structure in rural area is necessary, and then the exchange of resources between urban and rural areas has also become a major option, which is referred to as

urban-rural symbiosis, especially exemplifying Asian features (Morioka, 2011). Thus, the complement between urban and rural areas will develop the future sustainable society depending on 1) natural resources such as biomass energy, organic compost, clean water and 2) traditional agriculture and land management for food self-sufficiency and safety and functional food production, 3) cultural diversity of life.

4.1.1 Rural-urban partnership with business sectors

Business-based partnerships should be developed. Tudan village can provide safe food for people in urban areas, food shops and stores. Biomass products such as charcoal, biochar, brick (including oil palm shell) and timber can also activate business sectors in urban cities like Kota Kinabalu. Bio-waste such as kitchen waste produced from hotels and households in urban areas is usefully for making composts for fertilization in rural areas. Urban areas should provide technical and financial support, if necessary, thereby developing a base of business collaboration between rural-urban areas. Eco-tourism is another option for developing new rural-urban collaboration. Natural landscapes, safe food, natural products and friendly people with traditional culture in rural areas can attract many tourists. Through such rural-urban partnerships, new business models might be established, which utilizes added-value of Tudan village products such as safe food (no-chemical contained food) and UNESCO MAB branding.

4.1.2 Rural-urban partnership through education and cultural exchange

Rural areas provide educational programs and cultural events for urban people. These functions could be a driving force for awareness among urban people through gaining traditional knowledge as sustainable resource management, some hands-on activities, and traditional cultural values of human-nature harmonization, giving impacts on urban life-styles and their mindset towards the environment. Furthermore, this rural-urban partnership can create new educational program with a concept of ESD (Education for Sustainable Development). Through these rural-urban partnerships, local communities are proud of their identity, which is a base for their self-defined development. In the case of Tudan village, communities are proud especially of their traditional agriculture as embodying their own traditional identity. Appropriately recognizing and supporting local identities and cultures can build social cohesion and pride in the community, which encourages them to contribute to sustainable resources and land management as a result. It is not always easy for local communities to recognize their own local identities, however through environmental education and cultural exchange programs, local communities also learn more about the importance of sustainable resource management and come to feel the pride of their own culture. On a slightly different note but more importantly, the exposure of traditional culture and knowledge to the public may contribute to the preservation of such culture and knowledge.

4.1.3 Rural-urban partnership toward low carbon society and resource circulating society

As stated in session 3.6, Biochar which is made from abundant bamboo in Tudan village has a function for carbon storage and soil fertility. Traditional agriculture of slash and burn with less chemical fertilizers can also contribute to carbon sequestration in soil if slash and burn is applied by the appropriate methodology such as enough cropping intervals and the careful selection of slopes, because large amounts of Biochar by slash and burn stored in soil for a long time. These slash and burn practices in Tudan village will be counted as an offset of carbon dioxide emissions in the future. Community members of Tudan village are making composts from kitchen waste, weeds and damaged or rotten fruits, according to practices introduced by a JICA-sponsored project based on this thesis. If composting at Tudan village can be scaled up in the future, it might be possible to utilize waste from urban areas. Such composts can be commercialized and sold in the market. As mentioned in session 3.5 as well, material of brick houses in Tudan village comes from oil palm shells. This is also a huge potential for developing rural-urban partnerships through resource flows between rural-urban areas. The rural-urban partnership based on the concept of sustainable society such as low carbon society and resource re-cycling society is a new model in the future.

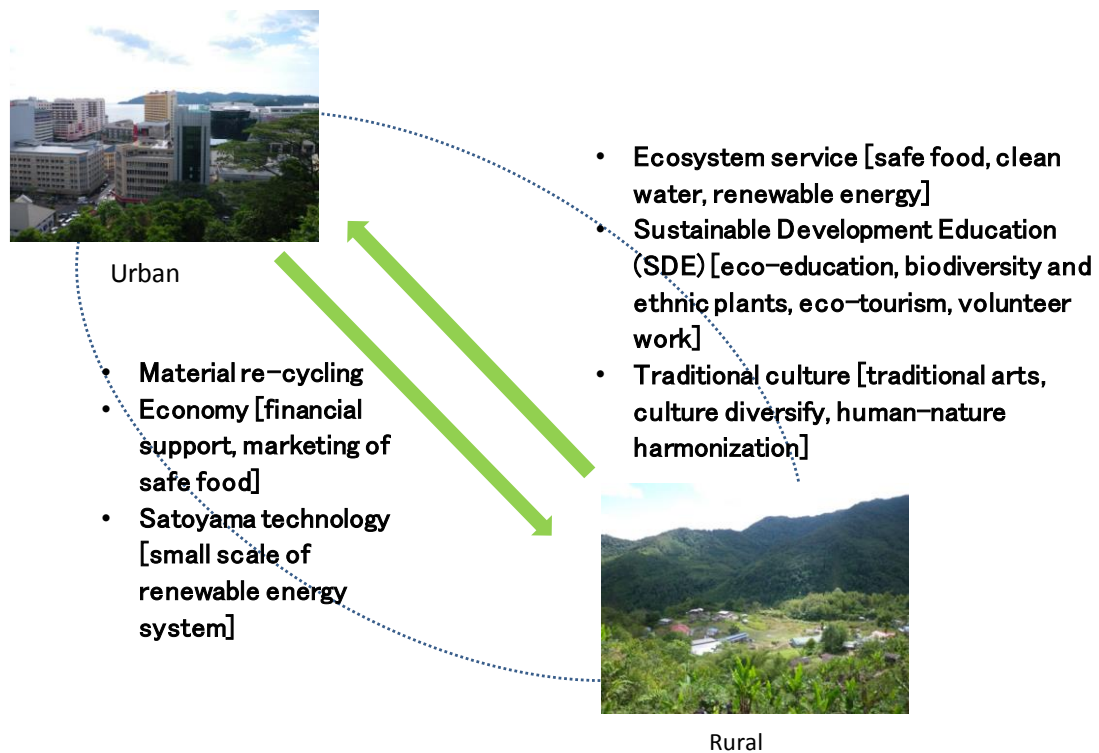


Figure 4.1 new society based on urban-rural partnership structure

4.2 *Satoyama* System Establishment as Sustainable Land Management

In this thesis, as an important aspect for realizing a sustainable society, food production and biomass energy potential were analyzed and visualized as a base for future actions such as policy planning and *Satoyama* technology development. In addition, as an important element for constituting a sustainable society, natural capital and happiness degree as social capital were also analyzed. Here, based on the results shown in this thesis, the research questions mentioned in Chapter 1, namely, ‘What are the indispensable components to establish the ‘*Satoyama*’ system?’ and ‘How the ‘*Satoyama*’ system can be maintained and strengthened?’ are discussed.

4.2.1 Enhancement of local capital

Unlike financial capital, some natural and social capital cannot be easily translated into economic value. Nevertheless, natural and social capital must be as equally evaluated as financial capital. In this thesis, social capital, which was closely connected with nature, in Tudan village were visualized by applying the *Satoyama* Agricultural Development Tool (SADT), and then the economic value of natural capital in Tudan village was evaluated. Unfortunately, but in many countries in general, environmental conservation is not a political priority agenda item. However, Sabah is a case where environmental conservation by various initiatives and advanced measures is being tackled such as nature-based tourism which is one of the biggest industries there. Nevertheless, data and information on the economic value of environment-related social capital and natural capital is still incomplete. Therefore, it is necessary to evaluate natural and social capital in rural areas. As a result, the underprivileged people, in rural

areas, who are heavily dependent on natural resources for their daily life, can be easily affected by environmentally-unconscious developments, such as large scale plantation agriculture, timber production and so on. In this regard, social and natural capital in rural areas must be duly valued for sustainable development, which is not treated as an external diseconomy (like environmental pollution), but equally treated with financial capital. Environmental policy should consist of three different elements in a well-balanced manner, namely 1) “command and control (like emission control and land use control)”, 2) “voluntary control and moral persuasion (like environmental education)” and 3) “economic Incentives and market-based mechanisms”. This well-balanced policy consisting of these three elements is called the Policy-Mix (Suzuki, 2014 and 2015). In the case of Sabah, a population explosion since the 1950s coupled with a trend of land consolidation into the hands of a few major companies and Sabah State government has made land a scarce resource. Its growing economic demand has been continuing to put pressure on the land use in rural areas. Especially, in the border of protected area, there are arguments and conflicts between governmental bodies and local communities in terms of natural resource and land use management. As Sabah has an environmental education policy, it is a very unique state among other states in Malaysia. Therefore, Sabah can be regarded as an advanced state in Malaysia in the context of environmental education (Suzuki, 2015). As a result, Sabah should develop more intensive environmental education to realize Policy-Mix for economic incentives and market-based mechanisms, which could become key policy instruments for the realization of a sustainable society in the future in Sabah. In this context, PES (payment for ecosystem services), among other things, is one of the excellent tools for Policy-Mix. In developing PES scheme and framework, social and natural capital in the target areas

should be duly recognized, well analyzed and fully valued.

4.2.2 Important elements for *Satoyama* System Establishment

It is urgent to reduce the dependence on petroleum as a source of energy and change such petroleum-dependent societies to sustainable ones. Simply, our society requires food and energy independence so that the area either at the national, regional and local level can become independent (Osaki, 2011). This thesis demonstrated the potential of the independence of food production and energy usage at the local level, by focusing on Tudan village showing that it had the potential to build a self-sufficient structure in the aspect of food production and biomass energy. If Tudan village can establish a self-sufficient structure, Tudan village could become a model local low carbon society and resource circulating society in Sabah, and also in several similar regions in the world.

Satoyama is not just a concept about land scape, but rather should focus on a more self-sufficient or self-standing regional structure with the concept of integrated food-energy-carbon management. *Satoyama* technology, which combines scientific and traditional technologies, depend basically on low-intensity energy such as renewable energy, especially biomass in Sabah. Integrated management system with appropriate technology (here, *Satoyama* technology) is an indispensable and important element for *Satoyama* System Establishment, and actual practices of such a system in the region can help to sustain land management and food production and enhance the regional economy.

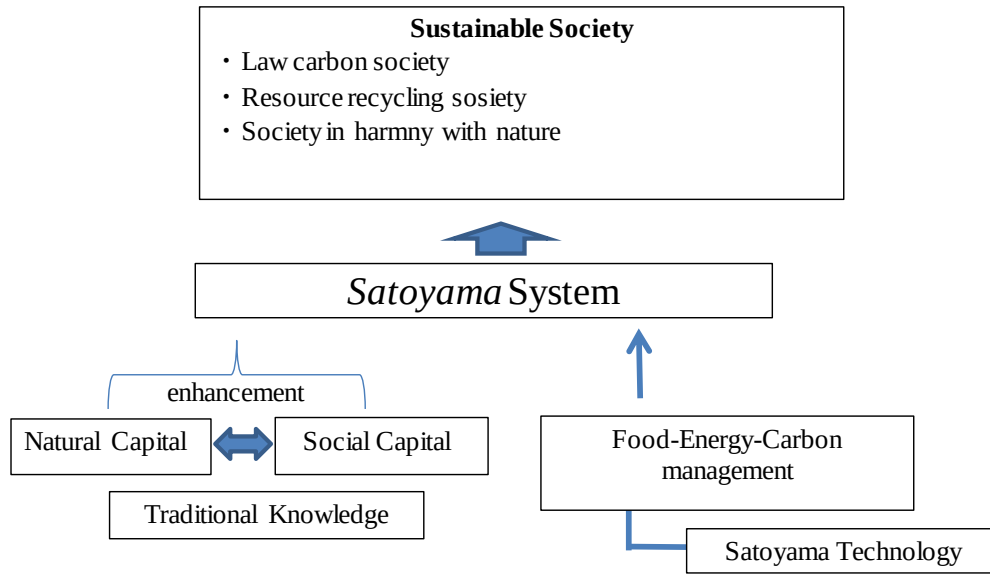


Figure 4.2 Conceptual framework for *Satoyama* System Establishment

4.2.3 Future perspective of the *Satoyama* System

Osaki (2014) described the *Satoyama* System as a sustainable land management for long term in East, Southeast and South Asia (called an Asian Crescent) (Osaki 2014), which maintains the independently coexistent system of society (*sato*) and nature (*yama*). Borneo Island where Sabah State, Malaysia is located is a typical and representative example of the *Satoyama* System. Borneo Island is rich in biodiversity and high carbon reservoir ecosystems (Osaki 2014). Rich and large forests serve as a carbon sink and stock, which contribute to the balance of carbon on a global scale. Also, the forests of the Borneo Island reserve large amounts of water. Therefore, if the natural ecosystems in the Borneo Island are destroyed, the global ecosystem and environment will be negatively affected, and large amounts of carbon emissions and water deficiency will affect and accelerate climate change. Therefore, the conservation of the *Satoyama* System in Borneo Island is one of the keys for conservation of the global environment

and ecosystem.

The *Satoyama* System in this thesis stands for a biological production system which can be found in the Asian Crescent. The *Satoyama* System in Sabah is created and developed by utilizing abundant natural resources and traditional agricultural practices with less impact on the environment. The *Satoyama* System in Sabah plays an important and essential role in 1) stabilizing land and climate, 2) sustaining livelihood, 3) enhancing local economy, and 4) contributing to environmental education. Further research that was unable to be included within the scope and depth of this thesis includes water resources. The environment, ecological and geological features of the Asia, or Borneo Island particularly are strongly depend on abundant water resources. This thesis, however, provides some thought-provoking ideas to strengthen the *Satoyama* System and expand it to other areas regionally and globally. Also practices at Tudan village can be shared with other areas not only in Sabah State but the Borneo Island as a whole. This will contribute to development of a sustainable society in the local and regional area even in the global context.

Chapter 5 Summary

In the twentieth century, large amounts of natural resources including food and energy were used to maintain a lifestyle of mass production, mass consumption and mass disposal. In the twentieth century agricultural system, “converting oil into food” was dominant, which was referred to as "Fossil Fuel Orientated Agriculture". Considering the limitation of such resources on earth, this type of lifestyle in the twenty-first century has to be changed and there have been strong desires and pressing needs to build a sustainable society where limited resources can be used in a sustainable manner. Our challenge is to reduce the dependence on petroleum as a source of energy and change such a petroleum-dependent society to a sustainable one. In other words, our society requires food and energy independence so that the area either at the national, regional and local level can become independent.

Thus, a sustainable society, especially in rural or local areas, should construct a sustainable system based on food self-sufficiency and renewable energy usage, and also on economically enhanced mechanisms such as Natural Capital, Carbon Credit, Ecosystem Service (Payment for Ecosystem Service, PES), Ecotourism, and so on. In this context, the establishment of the *Satoyama* system is a promising way to move forward to realize a sustainable society. The ‘*Satoyama* System’, which expresses a stratification to effectively use the universally available low intensity solar energy based on the idea of a society with nature-human coexistence.

This thesis is therefore aimed at examining the possibility of establishing an integrated *Satoyama* System in Sabah, Malaysia with a focus on food security, biomass energy potential and social and natural capital. The key element of the ‘*Satoyama* System’ in Asia is the food- energy-carbon management system which enforces the

sustainable biological production potential that has been established over a uniquely long span of years. To propose and establish an "Integrated Sustainable Land Management System", this thesis analyzed the food-energy based sufficiency and potential of biomass energy derived from oil palm, forest, rice, coconuts and livestock in Sabah for the first time. Then, as a case research, Tudan village in Sabah was selected to analyze food security, biomass energy potential and natural and social capital.

It was found by analyzing sets of data of 2010 that food self-sufficient ratio in Sabah was 46.40%. Population growth and land for food production could be a factor giving a big impact on the ratio. A rough simulation was carried out for future forecast. First case is based on the scenario that population in Sabah continues at the pace of 2%. In this case, food self-sufficiency ratio is slightly down to 45.49 %. Considering that rice remains as the most important staple in Sabah as the Agriculture and Food Industries Minister in Sabah declared, the next scenario was designed for taking the area for rice production into consideration. In addition to a continued population growth of 2%, if the rice production area decreases by 5 % per year, the ratio goes down to 44.47%. It is no doubt that population growth and area scale for food production influences food self-sufficiency.

In the meantime, biomass energy potential in Sabah was analyzed as around 65,590,323 GJ/year, which was derived from oil palm (EFB: Empty Fruit Bunch and shell), coconut shell, rice, livestock and forest. Most biomass energy came from oil palm, which was around 62,045,584 GJ/year. If this total energy potential is applied at a power plant with an efficiency ratio of 25% and 8,000 hours per year of operation, this has the potential of 572 MW, which is equivalent to the electric power of one small nuclear plant in Japan. This amount of energy from oil palm residues is equivalent to

around 90% of the total supply of electricity in 2010 ($5,105.4\text{GWh}/8000\text{h}=638\text{MW}$) in Sabah. Translating this total biomass-derived energy potential into monetary terms by referring to FiT (Feed-in-Tariff) rate for biomass, it is equivalent to around 1,240 Million RM per year (1RM: Malaysian Ringgit $\div$ 0.24USD). Sabah has a huge potential of biomass energy.

Looking at the local situation at Tudan village, it was revealed that around 50% of the total energy consumption in the village came from gasoline. It was because Tudan village has no public transportation, so people need to go to the neighboring town by their own means. Therefore, the portion of gasoline amount used out of the total consumption was high. On the contrary, it was also found that Tudan had a huge potential of biomass energy derived from forest, livestock waste and rice, which covers around 74 % of total energy consumption. This indicates that Tudan village has the potential for building a self-standing structure in terms of energy.

Happiness survey was conducted to evaluate human interaction with nature to identify issues for realizing human-nature coexistence society. Happiness survey indicates that local farmers are proud of the clean environment, traditional agriculture in the village while they put more priority on solidarity and cohesion among communities, and a peaceful life. It is of course that local communities are facing challenges and difficulties in their daily life such as the acquiring of daily goods, disasters (such as land slides), communication with government, to name a few. These can be regarded as social capital which needs to be taken into consideration in developing the *Satoyama* System. In addition to social capital, natural capital is also indispensable for realizing a human-nature coexistence society. The natural capital is fundamental to our well-being and their daily use remains almost undetected within our economic system. In this light,

this thesis analyzed natural capital value at Tudan village. As public interest functions of forests, fossil fuel substitution effect by using biomass, function for flood mitigation and water storage were analyzed. At same time, public interest functions of agricultural land, such as global warming effect by gas emission, function for flood prevention and soil erosion prevention were analyzed. Though all natural capitals cannot be easily evaluated in economic value terms, natural capitals with a potential to be carefully studied and enhanced in future were identified. Biodiversity-related capitals such as traditional herbal plants, carbon storage function by bio char, and traditional agriculture with less chemical fertilizer, to name a few, were among them.

Food security, utilization of biomass energy, and enhancement of natural and social capital are key concepts to achieve the *Satoyama* System which is based on a 'low-carbon society', a 'recycling society', and a 'society in harmony with nature'. Such concept needs to be realized in an integrated manner through the establishment of industry- and ecosystem- based regional partnership (urban-rural partnership).

In conclusion, this thesis presented a situation of biomass potential energy and energy based food self-sufficiency by districts in Sabah, and discussed possible future actions and perspectives. This research is the first of its kind. Also the thesis for the first time evaluated social capital (happiness degree) and natural capital in Tudan village as well as energy consumption-potential structure in the village. This thesis visualized the overall picture of the necessary components of *Satoyama* System in Sabah, Malaysia for the first time. And then the thesis discussed future perspectives for a sustainable society in Sabah such as the possibility of developing urban-rural partnership and future perspective of *Satoyama* System in the Asian Crescent by answering the questions,

What are the indispensable components to establish the ‘*Satoyama*’ system?’ and ‘How the ‘*Satoyama*’ system can be maintained and strengthened?’ were discussed.

It is expected that the results of this thesis will be referred to and be utilized as a baseline, reference data or a guiding framework for designing *Satoyama* System in future in Sabah and can be replicated and modified to other sites in Malaysia and beyond.

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Appendices

Appendix 1	Energy based food self-sufficiency potential in Sabah
Appendix 2	Energy based food self-sufficiency potential in Sabah (Simulation 1: population growth 2 %)
Appendix 3	Energy based food self-sufficiency potential in Sabah (Simulation 2: population growth 2 % + rice production area decrease 5 %)
Appendix 4	Result of SADT of Tudan village
Appendix 5.1	Raw data of Happiness Survey ~ Respondents
Appendix 5.2	Raw data of Happiness Survey ~ Response

Appendix 1 Energy based food self-sufficiency potential in Sabah

Districts		Supply														Self-sufficiency ratio (%)																	
		All Industrial Crops (Crustal)				Agricultural Crops (Crustal)				All				Livestock						All Fish		All Fish		Consequence of food self-sufficiency ratio (%)									
		Cereals	Coffee	Paddy	Sugar Cane	Ten	Tobacco	Sago	Fruit Crops	Leafy Vegetables	Root Vegetables	Cash Crops	Spices	Crops (Crustal)	Butter Beef		Cattle Beef	Pork	Chicken Meat	Duck Meat	Egg	Liquid Milk	Meat (Crustal)		Blackhead	Seaweed	Inshore Fish						
Total (Crustal)	9,173	3,167	2,801	118	0	0	0	0	6,186	11,479	852	261	0	2,780	1,754	16,584	0	23	2,278	432	14,882	5	382	5,022	17,864	5,088	4	13	22,181	26,718	37.17		
Agadez	30,417	5,584	150	0	0	0	0	0	5,734	1,486	211	138	0	9,363	55	11,653	0	0	0	0	0	0	5	10,773	290	2,163	0	0	13,225	88,372	34.03		
Adrar	31,568	5,817	60	0	0	0	0	0	5,877	4,731	2,882	1,078	15	6,612	26	15,356	13	473	576	65	0	0	0	11,28	6,274	265	17	9,236	134,096	23.56			
Annaba	14,758	69	566	0	0	0	0	0	635	43	161	66	0	936	11	1,199	0	0	0	0	0	0	0	12,501	346	56	0	12,934	40,743	36.17			
Arzew	45,446	12,32	288	2	0	0	0	0	1,532	2,899	2,346	932	0	1,230	22	6,839	0	0	4,397	13,424	405	2,886	127	0	16,752	153	0	23	16,527	265,166	17.18		
Batna	216	176	0	7	0	0	0	0	183	22	0	5	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	5	5	97,448	0.22	
Bordj	6,567	14	17	0	6,160	0	0	0	6,139	714	2	2	0	26	0	744	0	0	0	0	0	0	5	0	5	0	0	0	17	17	23,461	29.65	
Boumerdes	7,457	598	37	0	1,791	0	0	0	2,414	2,795	14	11	0	78	0	2,898	0	0	0	0	0	0	0	0	0	2,114	0	0	31	2,145	68,123	10.79	
Chlef	42,281	12,525	129	0	5,105	0	0	0	18,158	1,658	261	88	0	6,533	26	8,556	0	7	421	153	34	0	0	368	885	14,824	125	3	66	14,508	55,562	76.37	
Collo	38,368	9,741	20	2,4079	0	0	0	0	33,844	667	4	34	0	689	18	1,383	0	0	0	0	0	0	14	0	14	3,109	2	0	1	3,112	23,129	152.62	
Constantine	53,415	4,422	178	0	45,933	0	0	0	50,553	1,832	86	95	0	415	37	1,933	0	44	216	0	0	0	0	689	206	3	0	51	260	44,268	120.66		
Djelfa	80,075	200	179	28	73,742	0	0	0	74,238	9,348	148	154	0	1,728	165	10,437	34	306	0	0	0	0	0	60	308	3,285	672	0	51	4,007	69,640	147.47	
El Oued	60,919	144	1,572	23	21,520	0	4,124	0	27,342	12,077	14,332	1,786	61	3,382	51	31,923	3	13	223	9	0	0	0	40	288	0	0	0	956	956	62,101	96.97	
El Tarek	64,657	101	3	3	13,565	0	0	0	13,672	9,966	1,711	13,146	46	7,730	237	21,035	0	0	350	25,059	0	3,221	148	154	283,52	343	876	0	128	1,348	63,347	95.04	
El Yennayer	74,925	17	11	0	244	0	0	0	272	1,305	688	424	0	1,297	27	4,248	25	140	13,813	9,823	878	4,875	116	0	298,78	40,386	0	0	0	40,386	300,111	24.05	
Evreux	14,712	0	63	0	3,553	0	0	0	3,656	2,610	2,349	690	3	1,990	63	7,706	0	0	2,052	1,080	97	13	33	32,782	0	0	0	74	74	8,1622	18.02		
Evreux	74,591	609	10	5	6,995	0	0	0	2,485	1,058	2,544	1,174	0	645	188	7,237	0	0	34,925	0	15,127	0	295	50,346	6,440	87	0	346	6,674	83,236	89.56		
Evreux	45,231	679	0	4	7,848	0	0	0	30,252	37,568	688	95	0	77	21	3,366	0	0	2,189	0	0	0	0	274	2,457	1,281	1	0	43	1,424	43,047	105.07	
Evreux	21,964	291	86	201	9,498	0	0	0	10,078	9,114	723	300	0	290	89	10,521	0	0	0	0	0	0	0	0	1,274	0	0	83	1,357	23,184	94.70		
Evreux	22,381	0	0	0	793	0	0	0	12,062	15,633	451	14	7	0	0	481	1	0	131	0	0	0	27	159	6,092	13	0	3	6,108	12,593	177.73		
Evreux	29,686	0	881	680	28,966	0	0	0	29,845	7,782	53	448	0	182	46	8,488	34	39	217	0	14	0	0	703	1,007	0	0	0	338	338	36,688	108.15	
Evreux	44,568	106	337	233	29,343	0	0	0	30,019	3,659	2,138	917	12	1,089	39	7,231	0	333	800	1,834	41	1,174	0	2,752	6,938	0	0	0	385	11,5215	38,68		
Evreux	19,158	15	188	42	17,729	0	0	0	17,884	197	190	98	0	0	45	494	0	0	111	0	0	0	0	111	0	0	0	676	676	23,529	81.42		
Evreux	6,296	2	120	5	5,895	0	0	0	5,886	32	0	6	0	0	134	0	165	0	0	0	0	0	0	0	0	0	0	0	159	159	28,984	38.08	
Evreux	947,715	47,866	7,705	1,273	30,1388	0	4,124	0	45,699	480,055	87,191	32,332	10,070	137	47,661	29,43	189,334	180	1,387	23,783	124,586	2,882	41,272	434	5,497	200,652	144,384	333	2,490	3,467	138,673	2,943,525	46.40

Appendix 2 Energy based food self-sufficiency potential in Sabah (Simulation 1: population growth 2 %)

Energy based food self-sufficiency potential in Sabah Simulation 1: population growth 2 %

Districts	Total (Gcal)	Supply																							Consumption on Total (Gcal)	Self sufficient ratio (%)							
		All Industrial crops (G cal)							All Agriculture Crops (G cal)							Livestock																	
		Cocumind	Cocoa	Coffee	Paddy	Sugar Cane	Tea	Tobacco	Sago	Fruit Crops	Leafy Vegetable	Root Crops	Spices	Oil Crops	Agroforestry	Buffon	Outle Beef	Pork	Chicken Meat	Duck Meat	Chicken Eggs	Duck Eggs	Liquid Milk	All Livestock (Gcal)			Fish	All Fish (Gcal)					
Tawau	99,373	3,187	2,901	118	0	0	0	0	6,186	11,409	852	261	0	2,708	17,94	18,984	0	23	2,728	35,471	432	14,882	5	382	54,022	17,964	5,098	4	13	22,181	272,684	36.45	
Semporna	30,417	5,584	150	0	0	0	0	0	5,734	1,486	211	138	0	9,563	55	11,453	0	0	0	0	0	0	5	0	1,120	9,278	290	2,161	0	12,225	91,159	33.37	
Uluabau	31,588	5,917	60	0	0	0	0	0	5,937	4,731	2,892	1,078	15	6,812	28	15,356	13	473	576	65	0	0	0	0	0	666	265	17	9,226	130,777	23.09		
Kuruk	14,739	89	566	0	0	0	0	0	635	43	161	68	0	926	1	1,198	0	0	0	0	0	0	0	0	0	1,501	346	56	0	12,904	41,557	35.47	
Sandakan	45,540	1,232	298	2	0	0	0	0	1,532	2,306	2,846	932	0	1,230	22	6,839	0	0	4,197	13,424	405	2,096	127	0	20,300	16,752	153	0	23	16,927	270,470	16.84	
Kuching	216	176	0	7	0	0	0	0	183	22	0	5	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	5	99,397	0.22	
Tongod	6,937	14	17	0	6,160	0	0	0	6,191	714	2	2	0	26	0	744	0	0	0	0	0	0	5	0	5	0	0	0	0	17	23,930	29.07	
Beluran	7,437	586	37	0	1,791	0	0	0	2,414	2,795	14	11	0	78	0	2,898	0	0	0	0	0	0	0	0	0	0	0	0	0	31	2,145	70,506	10.58
Kudat	42,281	1,225	129	0	5,105	0	0	0	18,188	1,650	291	80	0	6,533	26	8,550	0	7	421	153	34	0	0	308	983	14,392	125	3	69	14,589	584,470	74.87	
Pitas	38,350	9,741	20	2	24,079	0	0	0	33,841	667	4	34	0	659	18	1,383	0	0	0	0	0	0	14	0	14	3,109	2	0	1	3,112	25,831	148.63	
Kota Marudu	53,415	4,422	178	0	45,953	0	0	0	50,553	1,302	86	93	0	415	37	1,933	0	44	216	0	0	0	0	0	0	669	206	3	0	51	260	45,153	118.30
Kota Belud	89,073	290	179	28	73,742	0	0	0	74,239	8,240	149	154	0	1,728	165	10,437	24	306	0	0	0	0	0	0	0	390	3,285	672	0	51	4,007	61,611	144.57
Renuar	60,219	144	1,572	23	21,520	0	4,124	0	27,382	12,077	14,332	1,788	61	3,282	51	31,592	3	13	223	9	0	0	0	40	288	0	0	0	0	956	63,343	95.07	
Tuaran	64,957	101	3	3	13,565	0	0	0	13,672	9,866	1,711	1,316	46	7,710	257	21,005	0	149	13,813	9,823	878	3,221	148	154	28,932	343	878	0	128	1,348	69,714	93.18	
Kota Kinabalu	74,582	17	11	0	244	0	0	0	272	1,305	690	424	0	1,797	27	4,243	25	149	13,813	9,823	878	4,875	116	0	29,678	40,388	0	0	0	40,389	306,113	24.36	
Penampang	14,712	0	63	0	3,593	0	0	0	3,656	2,610	2,249	690	3	1,990	65	7,706	0	0	0	2,552	1,080	97	13	33	3,276	0	0	0	0	74	83,254	17.67	
Papar	74,551	609	10	5	6,995	0	0	0	10,104	2,688	2,544	1,174	0	645	186	7,237	0	0	0	34,825	0	15,127	0	295	50,346	6,440	87	0	346	6,874	84,821	87.80	
Beaufort	45,231	679	0	4	7,048	0	0	0	37,894	2,563	610	95	0	77	21	3,386	0	0	0	2,183	0	0	0	274	2,457	1,381	1	0	43	1,424	43,808	103.01	
Sipitang	21,954	291	86	201	9,488	0	0	0	10,076	9,114	723	300	0	298	86	10,321	0	0	0	0	0	0	0	0	0	0	0	0	0	83	1,357	23,647	92.84
Kuala Penyu	22,381	1,978	0	0	793	0	0	0	12,982	15,633	451	14	7	0	0	481	1	0	131	0	0	0	0	27	159	6,092	13	0	3	6,108	12,845	174.24	
Tenom	39,680	0	881	600	28,366	0	0	0	28,847	7,782	53	443	0	182	48	8,488	34	39	217	0	14	0	0	703	1,007	0	0	0	0	339	339	37,422	106.03
Keningau	44,588	106	337	233	29,343	0	0	0	30,019	3,059	2,138	917	12	1,069	36	7,231	0	333	800	1,834	41	1,174	0	2,752	6,935	0	0	0	0	385	385	117,519	37.92
Tambunan	19,158	15	88	42	17,739	0	0	0	17,864	197	190	59	0	0	49	494	0	0	111	0	0	0	0	0	111	0	0	0	0	670	24,000	79.83	
Naharian	6,299	2	120	5	5,855	0	0	0	5,963	32	0	0	0	134	0	166	0	0	0	0	0	0	0	0	0	0	0	0	0	150	190	21,383	29.49
	947,715	47,866	7,705	1,273	301,389	0	4,124	0	469,99	408,055	87,181	32,332	10,070	137	47,661	2,943	180,334	100	1,387	23,783	124,996	2,882	41,572	434	5,497	200,692	144,394	8,333	2,490	3,457	156,673	2,083,376	45.49

(Simulation 2: population growth 2 % + rice production area decrease 5 %)

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Appendix 4 Result of SADT of Tudan village

1) Cyclic Use of Natural Resources

Questions	Answers	Total Possible Points
Is there diversity in land use? (Grassland, forest, cropland, irrigation ponds, human settlements, etc)	4	5
Is there evidence of good nitrogen fixation?	3	5
Is there an absence of soil erosion?	4	5
Is there an absence of soil degradation?	4	5
Has the number of keystone species been maintained?	4	5
Are other types of farming practiced instead of mono-cropping?	5	5
Are pesticides use avoided or minimized?	3	5
Are biopesticides and biological pest control being used?	4	5
Is there an absence of fish kills or algae bloom?	5	5
Total	36	45
Percentage	80	

2) Resource Use based on Carrying Capacity and Resilience of Environment

Questions	Answers	Total Possible Points
Is the land size of the village yet to be legally demarcated?	3	5
Is there inadequate water supply for the residents?	5	5
Is there inadequate forest conservation and protection?	4	5
Is there evidence of tree species reduction?	4	5
Is there evidence of water pollution?	5	5
Is there evidence of air pollution?	5	5
Is there evidence of soil pollution?	5	5
Is there inadequate waste management in the village?	3	5
Is there an inadequate disaster preparedness plan in the village?	4	5
Is there evidence of overfishing?	5	5
Is there evidence of overhunting?	4	5
Is there evidence of overgrazing?	5	5
Total	52	60
Percentage	86.67	

3) Recognition of the Importance and Value of Local Cultures and Traditions

Questions	Answers	Total Possible Points
Are there cultural landscapes and/or archeological sites that are recognized in the village?	3	5
Are there unique art, craft and/or objects that are recognized in the village?	4	5
Are there cuisines that are typical and/or unique to the village?	3	5
Are there rituals/ceremonies that are typical and/or unique to the village?	4	5
Is there a local language preserved by the village?	5	5
Are there local skills and knowledge that are typical and/or unique to the village?	4	5
Is eco-tourism, agro-tourism and/or homestays promoted in the village?	1	5
Total	24	35
Percentage	68.57	

4) Collaborative Management of Natural Resources

Questions	Answers	Total Possible Points
Is the organizational structure of the community well defined with clear roles for all players?	4	5
Is there diversity and inclusivity in the decision making process?	5	5
Is there transparency in the decision making process?	5	5
In the event of conflict is there a good negotiation and mediation mechanism?	5	5
Is there good communication and dialogue among citizens?	4	5
Total	23	25
Percentage	92	

5) Contribution to Local Socio-Economies

Questions	Answers	Total Possible Points
Is the infant mortality rate less than 5 per 1000 births?	5	5
Is the life expectancy at birth more than 80 years?	5	5
Is the literacy rate in the community between 95 and 100%?	4	5
Is the crime rate less than 10 per 1000 persons in the community?	5	5
Is there a low incidence of alcoholism/drug addiction in the community?	2	5
Is most of the food consumed produced within the community?	4	5
Are most members of the community employed within the village?	3	5
Total	28	35
Percentage	80	

Percentage Key	Scale
High (80-100%)	Strongly Agree 5
Medium (60-79%)	Agree 4
Low (0-59%)	Neither Agree nor Disagree 3
	Disagree 2
	Strongly Disagree 1

Result: Characterization of Community

Principles	Percentage of Answers	Satoyama Points
Cyclic Use of Natural Resources	80.00	0.80
Resource Use based on Carrying Capacity and Resilience of Environment	86.67	0.87
Recognition of the Importance and Value of Local Cultures and Traditions	68.57	0.69
Collaborative Management of Natural Resources	92	0.92
Contribution to Local Socio-Economies	80.00	0.80
General Satoyama Points	81.45	0.81

Categories based on the General Satoyama Points obtained
Non Compliant (0-0.59)
In Transition (0.6-0.79)
Satoyama Like (0.8-1)

Appendix 5.1 Raw data of Happiness Survey ~ Respondents

FEMALE

Respondent	Age	Occupation
F1	35	Farmer
F2	29	Farmer
F3	45	Farmer
F4	41	Farmer
F5	32	Farmer
F6	59	Farmer
F7	29	Farmer

MALE

Respondent	Age	Occupation
M1	39	Farmer
M2	54	Farmer
M3	38	Farmer
M4	25	Farmer
M5	18	-
M6	42	Teacher
M7	28	Farmer
M8	36	Farmer
M9	48	Farmer
M10	42	Farmer
M11	32	Farmer
M12	-	-

Appendix 5.2 Raw data of Happiness Survey ~ Response

FEMALE				
Question	Very satisfied	Satisfied	Less Satisfied	Not Satisfied
A				
1	F1,2,3,5,6,7	F4		
2	F1,2,3,4,5,6,7			
3	F1,2,7	F5	F3,4,6	
4	F1,3,7	F2,4,5		F6
5	F2,3,5,6,7	F1,4		
6	F1,2,3,4,5,7			F6
7	F1,3,7	F4	F2,5	F6
8	F1,2,3,5	F4		F6,7
9	F1,3,4,5			F6,7
10	F1,2,3,4,5	F6		F7
11	F1,3	F4,5	F2	F6,7
12	F2,3,5	F1	F4	F6,7
13	F1,2,3,5	F4,7		F6
B				
1	F1,2,3,4,5,6,7			
2	F1,2,3,4,5,6			
C				
1	F1,2,3,5,6,7	F4		
2	F1,2,3,4,5,6			
3	F1,2,3,4,5			F7
4	F1,2,3,4,5,6			F7
5	F1,2,3,5,6	F4		F7
6	F1,3,5,6	F4		F7
7	F1,3,5	F4		F7
8	F1,3,4,5,7			
D				
1	F3,4,7	F1,5,6	F2	
2	F1,2,3,4	F5	F6	F7
3	F1,3,5,6,7	F4		
E				
1	F1,2,3,5,7	F4,6		
2	F2,3,5,7	F1,4	F6	
3	F1,2,3,4,5,7		F6	
F				
1	F1,2,3,4,5,7		F6	
2	F3,7	F2,4	F1,5,6	
3	F3,4,5,7	F1,2	F6	
4	F2,3,5,6,7	F1,4		
5	F1,2,7			
6	F1,2,3,5	F4	F6	
G				
1	F3,4	F1	F2,6	F7
2	F1,3,4		F2	F7
3	F1,2,3,4,6,7			
4	F1,2,3,4,6			F7
5	F2,3,7	F1,4	F6	
H				
1	F3,6	F1,2,4,5		F7
2	F1,2,3,5,7	F4	F6	
3	F2,3,7	F1,4,5	F6	
4	F1,2,3,5,7	F4	F6	
5	F1,2,3,5		F6	F7
I				
1	F1,2,3,4,5,6,7			
2	F1,2,3,5,6	F4	F7	
3	F1,2,3,4,5,6,7			
4	F1,2,3,4,5,7	F6		
5	F1,2,3,5	F4,6		F7
J				
1	F1,2,3,4,5,6,7			
2	F1,3,4,5,6	F2		F7
K				
1	F3	F1,2,5,7	F4,6	
2	F1,2,5,7		F4,6	F3
3	F7	F1,2,5		F3,4,6
L				
1	F1,2,3,4,5,6		F7	
2	F1,2,3,4,5,6,7			
3	F1,2,3,5,6,7	F4		
4	F7	F1,5	F2,3,4,6	
M				
1	F3,4,6,7	F1,2		
N				
1	F1 - Children; F2 - Children; F3 - With Own Children; F7 - Family			
2	F1 - Attending Church; F2 - Attend Church; F3 - Close Unity, Being Friendly, Relatives; F5 - Attend Church; F7 - Attend Church			
N				
1	F2,3,5,7	F4		
2	F3,5,7	F1,2		
3	F3,7	F4	F5	F1,2
4	F1,2,3,4,5,7			
5	F1 - Cool Weather; F2 - Having Electricity; F3 - In Harmony, Friendly, United, F4 - Have Roads into Village, F7 - Village Have Own Road			

MALE				
Question	Very satisfied	Satisfied	Less Satisfied	Not Satisfied
A				
1	M1,2,4,5,6,8,9,10,11,12	M3,7		
2	M1,2,4,6,8,9,10,11,12	M3,5,7		
3	M8,9,12	M5,7,10,11	M1,2,3,4,6	
4	M5,7,10,11	M1,3,12	M2	M4
5	M1,3,4,6,8,9, 10,11	M5,12	M2,7	
6	M8,9	M3,10,11,12	M1,2,4,5,6,7	
7	M8,9,10,11	M1,3,5,6,7,12	M2,4	
8	M8,9,11	M5,7	M1,2,10	M4,6,12
9	M8,9,12	M3,4,5,7,11	M1,2,6,10	
10	M11	M8,9	M1,2,3,5,7	M4,6,12
11		M3,11	M1,2,5,6,7,8,9,10,12	M4
12	M3	M11	M1,2,4,5,6,7,8,9,10,12	M1
13	M4	M5,11	M1,2,7,8,9,10	M3,12
B				
1	M4,6,8,9,10,11	M1,2,3,5,7,12		
2	M6,8,9,10,11	M1,2,3,5,7,12	M4	
C				
1	M2,6,8,9,10,11	M3	M4,5,7,12	
2	M2,4,6,10,11	M1,3,5,7	M8,9	M12
3	M2	M5,11	M3,4,7,8,9,10	M1,6,12
4	M2	M10	M5,7,8,9,11	M1,3,4,6,12
5	M2,4	M1,3,6,8,9,11	M1,5,7,10	M12
6	M6	M3,8,9	M1,5,7,10,11,12	M2,4
7		M6	M1,3,5,7,8,9,10,11	M2,4,12
8	M8,9	M3,12	M1,4,5,7,10,11	M2,6
D				
1		M3,8,9	M1,5,6,7,10,12	M2,4
2		M8,9,10	M3,4,5,7,12	M1,2,6
3		M3,6	M1,4,5,7,8,9,10	M2,12
E				
1	M2,4,6	M1,3,5,7,8,9	M10,11,12	
2	M2,4,8,9,10	M1,3,6	M5,7,11,12	
3	M2,4,8,9	M1,3,6,12	M5,7,10,11	
F				
1	M2,3,8,9	M5,7	M1,4,6,10,11,12	
2	M3	M4,8,9,12	M5,7,10,11	M1,2,6
3	M3,8,9		M4,6,10,11	M1,2,5,7
4	M3,8,9,10	M4,6,7,11	M1,5,12	M2
5	M3,8,9		M1,4,5,7,10,11	M6,12
6	M3,8,9	M10,11,12	M1,5,7	M2,4,6
G				
1	M8,9	M3,6	M1,2,4,5,10,11	M7,12
2	M1,3,4,6,8,9,10,11	M5,7,12		
3	M1,3,4,7,8,9,10,11	M5,6,12	M2	
4	M10,11	M3,5,7,12	M1,4,6	M2
5		M3,5,7	M1,2,4,6,8,9,10,11,12	
H				
1	M1,2,3,4,8,9,10	M11,12	M6	M7
2		M3	M1,4,5,6,7,8,9,10,11,12	M2
3		M3,6	M1,2,4,5,7,8,9,11,12	M10
4		M3	M1,2,4,5,6,7,8,9,10,11,12	
5	M8,9	M3,4,7	M1,2,5,10,11	M6
I				
1	ACTIVE	A BIT ACTIVE	LESS ACTIVE	NOT ACTIVE
J				
1	M1,3,8,9,10	M4,5,6,7,11,12	M2	
2	M1,8,9	M3,6	M2,4,5,7,10,11,12	
3	M3,4,6,8,9	M1,11,12	M2,5,10	M7
4	M3,6	M1,11,12	M2,4,5,7,8,9,10	
5	M2,3,4,6,8,9,11	M1,5	M7,10,12	
K				
1	M1,2,3,4,6,8,9,10,11,12	M5,7		
2	M1,3,6,8,9,11,12	M5,7,10	M4	
L				
1	M3,4,6	M1,5,7,8,9,10,12		M2
2	M8,9,10	M1,5,7	M6,12	M2,3,4
3		M1,4,5,7,10	M8,9,12	M2,3,6
M				
N				
1	M2,3,5,6,12	M1,4,8,11		
2	M3,6,12	M1,5	M2,4,8,11	
3	M2,6,8,12	M1,3,11	M4,5	
4	M1,2,3,4,5,8,11,12			
O				
1	M1,3,4,8,9,10,11,12	M5,6,7		
2	M3 - Always Be Open to Each Other; M6 - Increase More Recreational and Group Gatherings. Lessen Unbeneficial Activities; M8 - Good Farm Yield and Family Ties; M9 - Good Farm Produce and Family; M10 - Sports and Recreational Activities; M12 - Unity and Understanding among Family and Community			
3	M1 - Happy When Together With Communities; M3 - Being Happy Is A Good Thing; M6 - Be Happy And Pray To God, Be With Families, Have Understanding And Tolerance Within Communities; M7 - Peace And Quiet; M10 - Cool Weather And Have Interesting Attractions Such As Waterfalls; M12 - Peaceful Area, Good Weather And Good Infrastructure			
P				
1	M2,3,5,6,12	M1,4,8,11		
2	M3,6,12	M1,5	M2,4,8,11	
3	M2,6,8,12	M1,3,11	M4,5	
4	M1,2,3,4,5,8,11,12			
5	M2 - Farming & Animal Husbandry; M2 -Good Weather And Peaceful In Kg Tudan; M3 - Cool Weather; M4 - Proud Of Preserved Surroundings; And Cool Climate; M5-Cool Weather; M6 - Cool And Peaceful Surroundings And Conserved Environment; M7 - Cool Climate; M8 And M9- Local Fruit Produce And Festivals Such As Kaamatan And Christmas Community Gathering; M11 - Cool And Nice Weather; M12 - Good Environment, Have Unity Among Community			