SAGO PALM 18: 19－27 (2010)

Preliminary Survey on a Comprehensive Biomass Production Plan Utilizing Sago Palm Resources in East Sepik Province, Papua New Guinea

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Abstract: Increasing biomass production based on the large-scale developments of farm field in unutilized lands is one of the global issues that must be examined under the current increasing demands for biomass. Large areas of unutilized land remain, such as the grass lands and flood plain in East Sepik Province, Papua New Guinea, with rich precipitation and adequate temperature. Sago palm is one of the crops adapted to the local environment in this region but is currently used only by the local people as their staple food on a small scale. This study advocates for the development of a comprehensive biomass production base that includes sago palm plantation. According to the result of satellite image analysis and Shuttle Radar Topography Mission data, the available grass land area is considered to be 200,000ha with a topography that changes from hilly to flat from north to south. The area near the flood plain of Sepik River is flat and low as a result of which water logging usually occurs in the rainy season. Pedological survey results show heavy clay distribution on a large part of the site. With regards to the topographic and pedological characteristics, a diversified plantation is an alternative idea for farm field extension. In such a plantation, each crop is planted in the zone with the most appropriate environmental conditions, sago palm being one such crop.
Key words: biomass, Papua New Guinea, remote sensing, sago palm, soil, topography

パプアニューギニア国イーストセピック州におけるサゴ資源を活用した総合的バイオマス生産に向けた現地予備調査

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要約　農業生産物の需要が増大する中で、未利用地における大規模な新規農地開拓を進め、バイオマス生産力を増強することは、避けては通れない地球規模で対応すべき課題の一つとなってきている。そうした中でパプアニューギニア国のEast Sepik州は草地や氾濫原などの未利用地が多く残されており、気候的に降雨量が豊富で高温であることから将来的に農業生産基地となることが期待されている。一方で同地域がその原産地とも言われるサゴヤシは、現状では地域住民が主食として自家消費向けに小規模利用しているに留まっている。そこで本研究では、同地域におけるサゴヤシを含めた総合的なバイオマス生産基地開発について検討した。本研究では草地を開発の対象とし、衛星画像解析などによってその面積と地形的な特徴を特定した。対象地域内におけるその面積はおよそ20万haであった。地形は北部の丘陵地から徐々に勾配が緩やかになり、南部ではより平坦となり、特にSepik川氾濫原

近くでは地形的に排水されにくく、雨期の湛水が懸念された。また、土壌調査を行った結果、対象地域の広くに重粘土が分布していた。こうした地形や土壌調査の結果から、対象地域をいくつかのエリアにゾーニングし、各エリアの環境条件に応じて複数の種の作物を栽培する多角的バイオマス生産基地が提案され、サゴヤシはその栽培対象の一つとして挙げられた。
キーワード：サゴヤシ、地形、土壌、バイオマス、パプアニューギニア、リモートセンシング

Introduction

The jump in crude oil prices and resulting higher food prices which we experienced in recent years points to the fact that the demand for biomass has become diversified and that biomass is used not only for food supply but also as an energy source. In some cases, biofuels made from food crops such as corn or soy bean have been criticized because of their impact on food prices. In fact, the corn which had been traditionally supplied to the food market is now being utilized for bioethanol production following the energy policy of the USA and has directly affected the market price of corn (Schnitkey et al. 2007). Strictly speaking, appropriate developments of bio-fuel in marginal land such as grassland, which has not been cultivated for food crops, does not compete with the food production.

Moreover, the demand for biofuels would be expected only in the next 30-50 years, when alternative energy technologies, such as fuel-cell and high-efficiency solar power generation, can be implemented. Shortly after the swell of biofuel demand, the size of the world population is expected to reach a critical stage, which will result in a serious food crisis. The new agricultural land being developed for fuel crops will be utilized for food production then. From that point of view, the large-scale development of farm fields in vacant or unutilized lands would be a global issue that cannot be avoided under the current increasing demands for biomass.

Papua New Guinea (PNG) has surplus land relative to its population density, which is 13 person/km^2, or 1/25 greater than that of Japan. Much of PNG is covered with rainforest, which serves as a sink of carbon dioxide that should be conserved. On the other hand, large portions of land are unutilized, such as the grasslands and flood plains in East Sepik Province, which could be developed for agricultural production to take advantage of their ample rainfall and high temperatures. Moreover, carbon stock in the grassland is very limited.

The area is a natural habitat for sago palm, a staple food for the local people (Shimoda and Power 1986, Amano and Toyohara 1995, Shimoda 2000). Sago palm produces a large amount of starch; therefore, it is possible that it could contribute to an increase in biomass production in the area.

However, because a 10-year period is required before the first harvest after a sago palm plantation is started, the most difficult problem is how sago palm farmers can sustain themselves in that period. Some earlier studies suggest that farmers could survive by using wild sago palm (JICA 1983); however, the starch content in wild sago palm is low, and it has very wide variation in yield (Shimoda 2000).

We believe that part of the grassland should be used for planting annuals or other crops that can be harvested within a few years of planting and produce a profit during the growth period of the sago palm. While waiting for the sago palm to mature, other crops could provide income.

In this study, we describe the environmental conditions of the area and the feasibility of developing a comprehensive biomass production base including a sago palm plantation. Irie et al. (2009) demonstrated that wild reed grass is a possible energy resource for ethanol production and that it would serve as part of a comprehensive development plan of the area;

however, the distribution of suitable areas for each crop relative to the environment was not discussed because of a lack of environmental data.

In this study, we propose an alternative that would create concrete zones for each crop, including sago palm, on the basis of the environmental characteristics and topography. In addition, we describe the current distribution of sago palm varieties (superior and wild) and suggest plans for future planting.

Materials and Methods

1) Processing satellite images and creating a digital elevation model

To determine the area of weed grasslands, unsupervised categorization is applied using the parameters of Band 1-6 of the LANDSAT Orth-rectified image of 16 September 2002. One satellite image covers the entire study site; therefore, the intensity of each band does not need to be calibrated. Nearly all of the area within the image is clear. Little cloud is covering the study site is negligible and no atmospheric collection was conducted. Data processing of the satellite image was carried out with Erdas Imagine (ESRI). The number of groups in the unsupervised categorization was increased from one to ten. Based on a comparison of the results of the categorization and the satellite pictures with the information of the coordination measured by GPS, the number of groups showing the most reasonable land cover identification was determined. Establishing 8 categories provided a clear definition of the grassland.

The National Aeronautics and Space Administration (NASA) of the U.S. conducted a Shuttle Radar Topography Mission (SRTM) in 2000. This digital elevation model is available at the following address: ftp://e0srp01u.ecs.nasa.gov/srtm/version2/. SRTM data is also processed with Erdas Imagine (ESRI) on a relief map with vertical cross sections.

2) Soil analysis

Soil cores were sampled from the surface layer (0-20 cm) with the use of 100 ml stainless sampling tubes in the field. The permeability, bulk density, and particle distribution of the sampled soil was measured in the laboratory. Permeability was measured with a falling-head permeability test (DIK-4012, Daiki Rika Kogyo). The weights of the dried soil cores were measured, and the bulk densities were calculated. Dried and crashed soil samples were sieved and separated into sand (0.02 mm-2 mm), silt (0.02 mm-0.002 mm), and clay (<0.002 mm).

Results and Discussion

1) Geographic characteristics of the study site

Figure 1 shows the location of the study site in East Sepik Province on the north bank of the Sepik River. Field exploration was conducted from a plane. Figure 2 is a photograph from the plane survey. The area is a weed field with a thick growth of trees along a tributary of the Sepik River.

The white area in Fig. 3 is grassland and weeds. The flood plain area spreading along the Sepik River is not supposed to be available for agriculture because

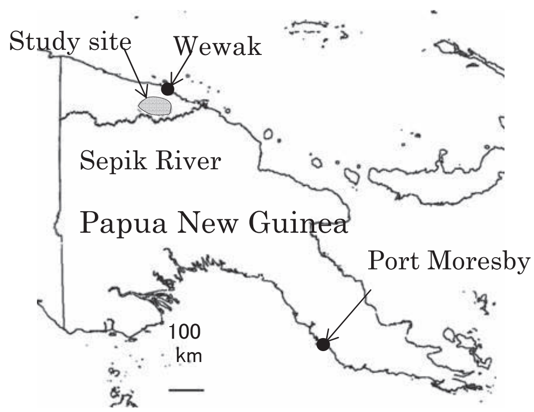

Fig. 1 Location of the study site in Papua, New Guinea.

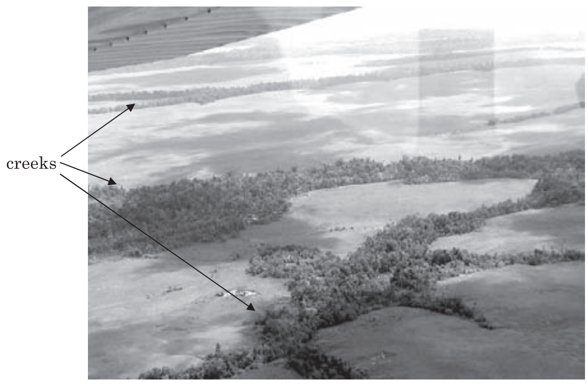

Fig. 2 Aerial photograph of grasslands and creeks.

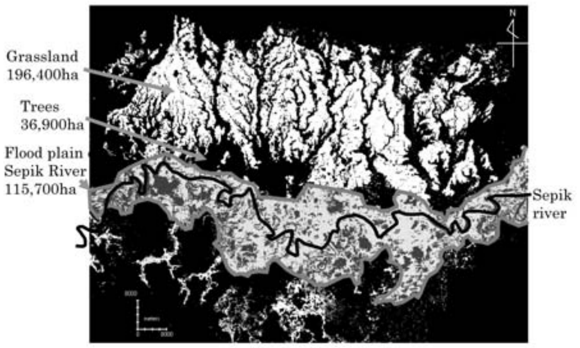

Fig. 3 Grassland distribution within the study site.

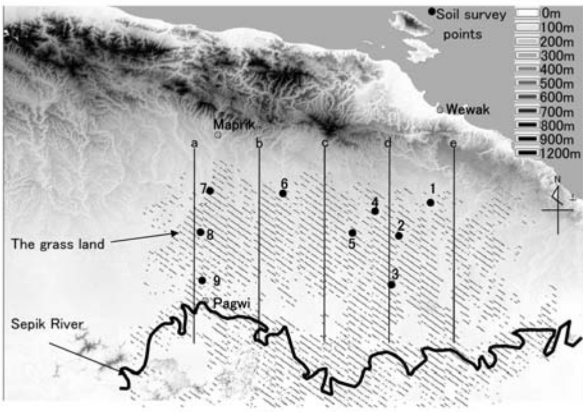

Fig. 4 Topographic relief map based on the Shuttle Radar Topographic Mission and soil sampling points on the map.

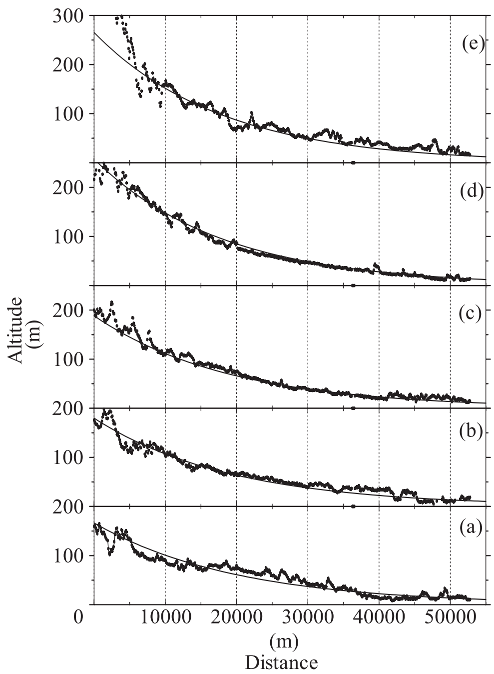

Fig. 5 Cross section on lines (a)-(e) in Fig. 4.

water logging was observed from the plane and the occurrence of frequent water stress was anticipated. Excluding the flood plains, the total available grassland on the north side of the Sepik River is 196,400 ha, while that in the flood plain is 115,700 ha. The total area covered by the creeks and the trees connecting to the creeks on the north side of the flood plain is 36,900 ha.

Figure 4 is a relief image of the topographic map based on SRTM. The hatched area is the grassland identified in Fig. 3. Figure 5 presents the cross section of Lines a, b, c, d, and e in Fig. 4 with the approximate curves. The north-south cross section shows the estimated exponential curve. The north side is hilly, and the south side near to Sepik River flood plain is flat.

2) Plan for the comprehensive biomass production base

Irie et al. (2009) demonstrated a basic plan for the comprehensive biomass production base, which we introduce briefly here. Three crops, cassava, sugar cane, and sago palm, which the local people have cultivated for years, were selected for the project. The three crops are well-adapted to the local environment. In addition, rice has been cultivated in the area for a short time. The environmental feasibility of rice adapting to the area has been demonstrated (JICA 2006).

There had been a plan to produce ethanol from these crops; however, the quantities of fossil fuels required for the saccharification and fermentation processes made the project unfeasible, according to the results of a life cycle assessment. Irie et al. (2009) suggested biomass power generation using local wild weed and grass covers for the energy requirements. Such power generation would be from renewable energy because the wild grass recovery rate is very high. Therefore, 20-30% of the grass land should be kept as an energy resource for supplying an ethanol production plant.

Sago palm resources within the study site

1) Sago palm planted along creeks

Local people within the study site and its outskirts populate the northern mountains rather than the southern flat lands because of the fertile soil, lower risk of contracting malaria, and windy conditions. The northern mountains are more populated than the southern flatlands. Most people live along the creeks due to the easy access to water. Superior sago palms are planted in the southern flat lands. The crop has a high starch content and is grown mainly along the creeks. However, the planted sago palms are managed by the local people as their staple food, and it would be impossible to count on the crop as a resource for ethanol production.

Previous studies (JICA 1983, Shimoda and Power 1990, Jong et al. 2006) showed that sago palm is planted on both wet and dry land. In fact, sago palms are planted in the northern mountains. In the southern flat lands, sago palm is planted along the creeks and on grasslands. Figure 6 is a photograph of the sago palms on the grasslands, which is an anomaly.

Fig. 6 Sago palm growing on grassland.

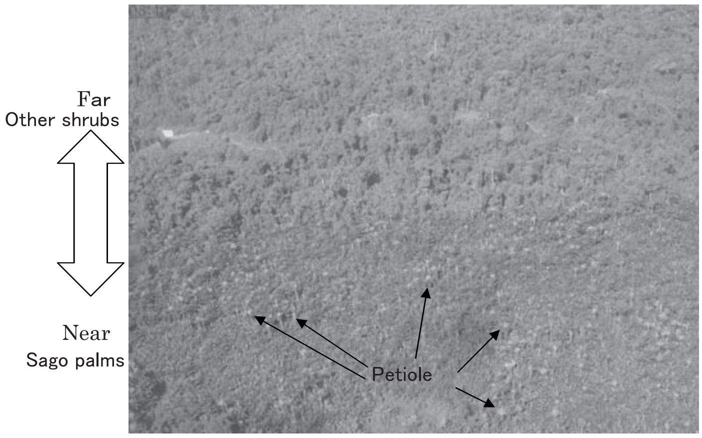

Fig. 7 Aerial photograph of wild sago palm trees.

According to an interview with the local people, the reason that sago palm is not planted on the grasslands is that the grass is burned during hunts for wild pig in the dry season. If sago palm were to be planted there, it would be burned with the grass during the hunting season. Therefore, the adaptability of sago palm plantation in a grassland environment is ensured, and sago palm could be a main crop in the study site.

2) Wild sago palm distribution

Figure 7 is an aerial photograph taken during the survey. It was taken in an area where there are many trees and not along the creeks (noted as “trees” in Fig. 3). The sago palm trees are shown in the foreground. The small white spots in the picture are the petioles of the sago palms. The shrubs in the background are not sago palms.

The area near the creek where the sago palm tree distribution is expected in the study site is about 36,900 ha. However, only 20-30% of the area is covered with sago palm on the basis of the aerial survey. Power and Ling (2006) estimated the area of wild sago palm forest in East Sepik Province (total area 4,000,000 ha) to be 500,000 ha. There was no explanation regarding how the calculation was done in the report, but they estimated the size of the area of the sago palm trees along the creeks and other water-logged areas as 30%. They showed that the poorly drained and swampy alluvial area in the Sepik River basin amounted to 1,500,000 ha. Based on the assumption that 30% of the creeks are covered with sago palm trees, the net area would be 11,070 ha. This is only 5.6% of the total area of the study site.

In addition, the height of those wild sago palm trees observed from the plane appeared to be low, but the density of the leaves was very high. It is assumed, therefore, that the wild sago palms are not maintained and excess suckers remain. The sago palm trunks are thin and, therefore, it is possible that they could be a profitable resource with adequate maintenance. However, currently, no revenue is anticipated from these wild sago palms.

Soil survey and zoning for 4 crops

1) Soil survey

JBIC (2009) carried out a soil survey in which the authors gave advice on determining the site locations. The locations of the soil survey points (sites 1-9) are shown in Fig. 4. The subsequent discussion is based on data of permeability, particle size, and bulk density. The report concludes that the hazard for agriculture in this area, in terms of soil properties, would be the drainage capacity.

Figure 8 shows the relationship between the permeability of the soil samples and the land slope. The land slope is calculated from the approximation curve of the topography on the north-south cross section. Examples of the approximation curve are shown in Fig. 5. This determination of the land slope is the same as that shown in JBIC (2009).

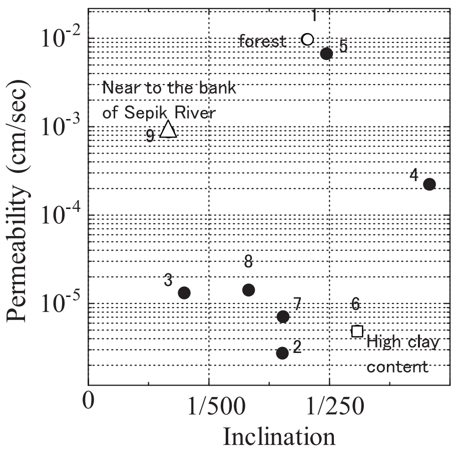

Fig. 8 Relationship between the slope of land and permeability of surface soil in the East Sepik area in Papua New Guinea. The numbers indicate the location in Fig.4.

The Hokkaido Central Agricultural Experiment Station (2002) shows several countermeasures to provide protection against the low drainage capacity of the soil, depending on the permeability of the surface layer. In this report, the permeability of 10^{-4} cm/sec is suggested as the threshold between light and serious low drainage capacities, and a suitable method is suggested for each. As shown in Fig. 8, sites 1, 4, 5, and 9 have comparatively better drainage capacity. On the other hand, the others have serious drainage problems.

The white circle in Fig. 8 represents the data of site 1 in the forest area. The forest area has adequate soil conditions. However, in this study, the target area for the development is grassland with the consideration of rainforest conservation. Site 1 is shown as a reference for ideal conditions.

The permeability of the soils sampled from the sites of the steeper grassland (sites 4 and 5) is the same as that of site 1 in the forest. The permeability of site 9, shown as a triangle in Fig. 8, is significantly higher, although the slope is gentle. Table 1 presents the particle distributions of the samples, which show that site 9 has a very high sand content. The Sepik River was probably the source of the sand, as its course changes in the flood plain from time to time. In the past, site 9 was probably affected by the river sedimentation.

Site 6, shown as a rectangle in Fig. 8, has low permeability, even though it is located on a steeper

Table 1. Bulk density and particle distribution of the soil samples collected from the East Sepik Plain

Sample No.	Bulk density g/cm³	Sand (%)	Silt (%)	Clay (%)
1	0.97	14	28	58
2	1.61	62	18	20
3	1.49	31	52	18
4	1.57	72	11	18
5	1.83	66	15	19
6	1.46	39	20	41
7	1.65	65	8	27
8	1.46	35	41	24
9	1.56	74	9	17

point. Table 1 shows that the clay content of site 6 is quite high. The reason for this is unknown. Perhaps the micro-topographic characteristics, such as a small depression, caused the accumulation of the clay. Site 1 of the forest reference data also has a high clay content. However, in the case of site 1 in the forest, the aggregation has already progressed. This is shown in the low bulk density (Table 1). Relative to that, only site 6 has a high content of clay among the 8 sampling sites in the grasslands, making it an exceptional case. Excluding sites 6 and 9, the results of permeability show higher permeability than 10^{-4} cm/sec when the slope is more than the threshold of 1/250.

In this discussion of the relationship between the limited results of the soil survey and the topographic characteristics of the whole study site, we estimate the spatial distribution of the drainage capacity, which might be a constraint on the agricultural activities within the site.

2) Zoning for 4 crops

With the consideration of the distribution of the drainage capacity in the study site, 4 candidate crops are selected. Each crop is suitable for the different drainage capacity, which is estimated from the topographic characteristics of the site.

Sago palm has tolerance for water stress, and rice paddy can be placed in wetlands with an adequate drainage system. Sugar cane can adapt to wet heavy clay under rich rainfall, such as that at the study site (Murayama 1985), but cassava is negatively affected by soil moisture. Soil amelioration will be considered, but the distribution of the original soil characteristics has to be considered when deciding which crops to use.

With regard to the estimated distribution of the drainage capacity, a slope with a grade of more than 1/250 is assumed to have permeability higher than 10^{-4} cm/sec, but it would have sufficient drainage capacity to keep the soil dry. At the same time, this slope would permit the implementation of surface water drainage. Therefore, an area with a slope of more than 1/250 would be adequate for cassava.

An area with an inclination of 1/500-1/250 could be drained of rain water by furrowing and ditching. Sugarcane, which is adapted to wet heavy clay (Murayama1985), could be cultivated on the land.

On land with an inclination of less than 1/500, with the implementation of an appropriate channel network system, rice paddy fields could be developed. However, in an area near the Sepik River, it would be difficult to implement a channel network to drain the excess water from the paddy field during the harvesting season, and there would be a risk of backwater from the Sepik River during the flood season. This area, which is considered to be the lowest point, could be used for planting sago palm (Shimoda 2000). The boundary between the rice paddy and sago palm fields will require more discussion, but, considering the distribution of the area with the trees in Fig. 3, an altitude of 30 m could be the border limit between the rice paddy and sago palm fields.

These criteria for the demarcation of the crops on the basis of the topography are characteristics of the study site.

Figure 9 contains the results of the demarcation for the 4 crops on the basis of the above topographic analysis. Table 2 shows the calculated ethanol production for each crop based on the statistical numbers of the yield of the crops and the required amount of crops for 1 kiloliter of the ethanol produced (International Fertilizer Industry Association 2005, NEDO 2004, NEDO 2007, JA 2007, JOMO 2001). The development area for each crop in Table 2 is defined as 70% of the area of Fig. 9. As reported above, 20-30% of the land will be used as grassland for the energy supply of an ethanol production plant. A production of about 592-783 kiloliters of ethanol is expected.

Conclusion

The topographic and soil characteristics of the grasslands in East Sepik Province were evaluated. Four crops adaptable to the local environment are

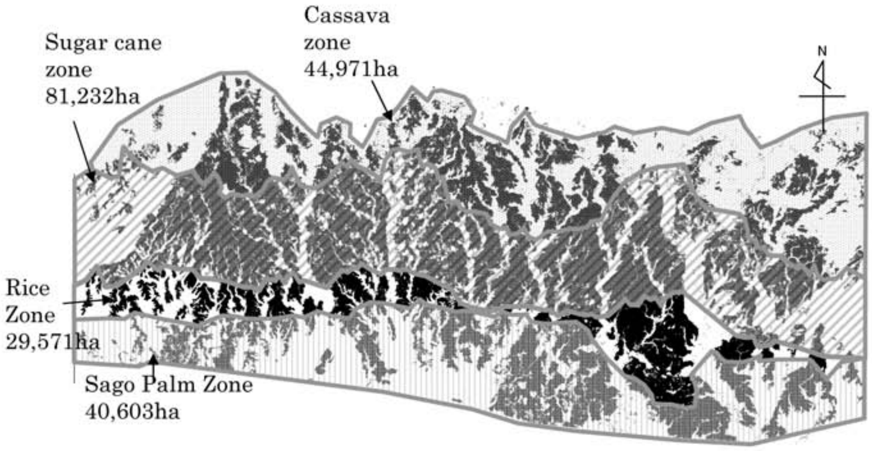

Fig. 9 Field demarcation of the grassland for 4 crops in the East Sepik Plain.

Table 2. Ethanol production capacity of each crop.

Crops	Sugarcane		Cassava		Rice (Hokuriku193)	Sago palm
	min	max	min	max		
Development area :70% of Fig.9 (ha)	56,862		31,480		20,700	28,422
Row material yield (ton/ha/yr)	51*1	69*2	16*1	31*3	10*4 (1 harvest a year)	40*3
Row material for 1kℓ Ethanol (ton/kℓ)	12.7*5		4.46*3		2.5*4	6.67*3
Ethanol production (10^3kℓ/yr)	229	309	110	221	83	170

Reference:
*1 International Fertilizer Industry Association 2005
*2 NEDO 2004
*3 NEDO 2007
*4 Zen-Noh 2007
*5 JOMO 2001

suggested for the establishment of a biomass production base. These crops could be planted in the locations with adequate drainage capacity. However, the actual adaptability of the crops to the site has to be examined on a small-scale pilot farm for further study. At the same time, soil amelioration for the improvement of drainage and harrowing has to be considered. One alternative for soil amelioration is the incorporation of organic matter, which would include the pith of sago palm after collecting the starch. This contingency could be studied on a pilot farm.

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