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Indonesian Staple Food Adaptations For Sustainability in Continuously Changing Climates

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Abstract

Climate change is a leading factor endangering sustainable food production, and numerous efforts have been enacted to prevent potential future food shortages. Most discussions and research have focused on how to sustain production through the development of new plant varieties that can adapt to changing environments. Drought- and heat-tolerant plants have been introduced to mitigate declining food production. Similarly, plant cultivation technologies have been developed to improve altered environments to be suitable for plant production. These efforts have focused on maintaining the food habits of populations in certain regions and countries. However, food availability may also be secured by changing the food habits of affected populations towards food resources that are relatively uninterrupted by climate change. In Indonesia, most of the population relies on rice as their main staple food; however, the production of rice is dependent on suitable climatic conditions, including rainfall, temperature and water. Resources such as the cassava and sago are not considered a main staple food, and their production is not significantly influenced by climate. This paper discusses the possibility of changing the staple foods of Indonesian populations to more reliable sources in areas affected by climate change.

Keywords: adaptation, cassava, climate change, food sustainability, sago, staple food

1. Introduction

Climate change has been a focus of discussion in numerous scientific and political arenas for many years, and it is defined as a significant and lasting change in the distribution of weather patterns over periods of decades to millions of years. In the context of agricultural production, climate change corresponds to a modification of rainfall that results in increased flood, drought or intense rain conditions. In addition, weather conditions are unpredictable, and their distribution is unstable (i.e., an increased or decreased frequency of extreme weather events) (Gosling et al. 2011).

Numerous researchers have argued that changes in weather conditions cause significant impacts and disruptions to agricultural production (Parrya et al. 2004; Jonesa and Thornton 2003), affect water availability (Barnett et al. 2005; Combalicer et al. 2010; Immerzeel et al. 2010; Ramanathan and Carmichael 2008; Vörösmarty et al. 2000), water and watershed systems (Johnson and Weaver 2009), and create social problems (Fischer et al. 2005; Wario et al. 2012). Consequently, the future food supply is not secure (Battisti and Naylor 2009; Brown and Funk 2008; Parry et al. 2005; Schmidhuber and Tubiello 2007). Therefore, agriculture adaptations must be developed in rapidly changing environments (Falco et al. 2011; Gebrehiwot and Veen A 2013; Howden et al. 2007; Iglesias et al. 2011; Lobell et al. 2008; Prato et al. 2010; Smit and Skinner 2002).

There has been extensive effort to develop crop plant varieties that have improved adaptability to rapidly changing environments and climate, and one of the most popular approaches has been the development of drought-tolerance plants (Cazares et al. 2010; Cattivelli et al. 2008). However, generating such plants is a complicated process that involves manipulating genes, cell structures and biochemical metabolic mechanisms; the results are also unpredictable and produce new challenges (Bradshaw and Holzapfel 2007; Mittler and Blumwald 2010). In addition, more radical approaches have been proposed, such as investment in agricultural adaptation measures (Halsnæs and Trærup 2009; Yao et al. 2007), the establishment of early warning systems and the creation of more effective development programs (Brown and Funk 2008; Chowdhury 2005).

Less attention has been given to food crops that are relatively undisturbed by climate changes because of the nature of their growth requirements. These plants, which are readily available for harvest, use and replanting (including varietal development), include cassava due its inherent tolerance to stressful environments (El-Sharkawy 2004; 2007) and undisturbed by climate change (Jarvis et al. 2012), and sago because of its high potential and underutilization (Flach 1983; Karim et al. 2008; Ohtsuka 1986; Stanton 1995; Tie et al. 2008).

Most of the Indonesian population relies on rice as a single staple food. The production of rice has been influenced by climate change, and significant fluctuations have been caused by flood and drought conditions (Iizumi et al. 2011) and rice production in middle income countries is especially vulnerable to droughts (Simelton et al. 2012). A clear argument has been presented that the future production of rice is uncertain and might decline as a result of water shortages, drought (Tao et al. 2006), pests and disease outbreaks (Mukesh et al. 2006; Muralidharan et al. 2003). These factors will likely be more intense in the future, thereby constraining efforts to improve production through intensification. In addition, extensification faces the problem of land availability and suitability as well as financing capacity. Therefore, the continued dependence on rice might place the population at risk of hunger because of future climate change. This paper discusses the possibility of changing the staple food of the Indonesian population from rice to relatively stable cassava and sago crops and concludes with recommendations on how to strengthen food security based on cassava and sago.

2. Rice Production and Its Disturbance

The government of Indonesia has been intensely involved in the rice economy to stabilize prices and expand domestic output to achieve national self-sufficiency in rice production. Because of numerous policies and programs, rice production achieved self-sufficiency in 1985, 2005 and 2013 (potentially). The Central Statistics Agency (BPS) of Indonesia estimated that paddy production was approximately 69.05 million tons (approximately 46.4 million tons, milled basis) in 2012. The actual production in the 2012 season in Indonesia as recorded by FAO (2013) included a harvest of 68.96 million tons (43.44 million tons, milled basis) from paddies, which was 362,000 tons more than previously estimated and 5% (3.2 million tons) greater than the 2011 level. Paddy production in 2013 was expected to reach approximately 72.1 million tons due to the expansion of rice acreage in the Kalimantan region and generally favourable weather during the growing period (Figure 1).

The highest average world rice productivity was 4.15 ton/ha in 2007 and was the result of long-term improvements starting in 1961, during which the production was 1.87 ton/ha. The increased production of rice in Indonesia has been a result of extensification and productivity enhancement, and production improved continuously over the period 2000-2013, which is classified as a medium global level (Bantacut 2012). Further improvements in productivity will be constrained by many factors, such as water availability and quality. Shortages of water during the dry season limit the total planting area, whereas excessive rainfall during the wet season causes flooding and submergence of paddy fields that may damage crops. In addition, there will be increased water-use competition between agriculture and other sectors in the future (Singh 2008) regardless of the potential for improving crop technology and genetic engineering (Khush 2002). Evidence suggests that the growth of rice productivity has declined meaning that the marginal productivity is close to reached its maximum and is levelling off. Many cases of harvest failure have occurred as a result of floods, droughts and unusual pest and insect attacks (Table 1 includes examples from local newspapers on planting failures; official figures were either unavailable or inaccessible). These facts supported a statement made by Douglas (2009) that flooding disrupted food production by more frequently and more severely than before.

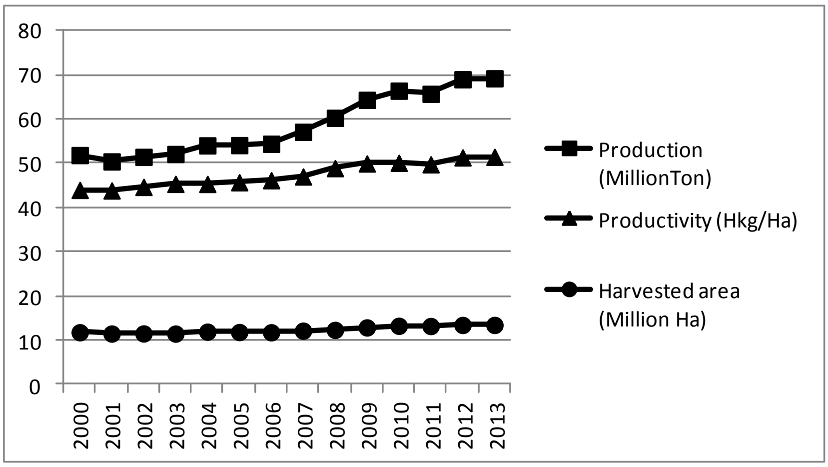

Figure 1. Indonesian rice production profile
(Source of data: BPS, Agriculture Statistics)

Table 1. Examples of reported failures of paddy harvest

Case	Year	Total Damage (ha)	Causes	Source (News Papers)
Aceh	2013	1,538	Flood	Waspada Online (Local News Paper)
	2011	125,000	Leafhoppers	Kompas 26-7-2011
East Java	2013	6,655	Flood	Actual.co 15-8-2013
	2013	659	Flood	Bisnis Indonesia 15-3-2013
West Sumatera	2013	2,200	Flood-Damaged Dam	Okezom.com 11-1-2013
Banten	2012	10,452	Drought	Tempo.co 26-11-2012
South Sumatera	2013	280	Flood	Sumatera Ekspres Online (10-4-2013)
West Java	2012	97	Drought	Pikiran Rakyat (31-8-2012)
West Nusatenggara	2012	2,928	Drought	MICOM 18-9-2012

Note: the figures are from local newspapers for the purpose of provide evidence and are not official data. Similar news reports have become more frequent in many newspapers and other media outlets (*e.g.*, seminars and broadcasts).

The current production levels cannot ensure future improvements because of many factors, although climate change in the primary influence. Naylor et al. (2007) categorized the effects of climate change in Indonesia (especially during El Niño events) in two important ways: (i) delayed planting in the monsoon season because of delayed rainfall and (ii) decreased planting during the crop year. These influences have caused a reduction in the net planting and harvesting areas and a larger deficit than normal in the annual rice production. Changes in climate and weather might profoundly affect the population dynamics and status of insect pest crops (Cammell and Knight, 1992). For example, temperature directly affects the survival, development, reproduction and movement of individual insects, thereby influencing the potential distribution and abundance of particular pest species (Thomson, *et al*., 2010). As a short-term solution, Amien and Runtunuwu (2010) proposed opportunities to utilize climate variability to enhance national food security and improve the welfare of farmers. This pattern highlights the importance of the timing of rice production. In addition to changing planting date, Mainuddin et al. (2011) underlined supplementary irrigation and increased fertilizer input as possible adaptation option strategies.

Changes in temperature and rainfall induced by climate change have the potential to interact with atmospheric gases, fertilizers, insects, plant pathogens, weeds and soil organic matter to produce unanticipated responses. Short-term strategies will not be effective against further changes in climate. Temperature increases of up to 2 ℃ have the potential to reduce the rice yield by 8.4% and cause a similar reduction in biomass and straw production although at a lower rate (Mathauda et al. 2000). A more accurate prediction based on weather data from 1979 to 2003 from the International Rice Research Institute Farm indicates that grain yield will decline by 10% for each 1 ℃ increase in the growing-season minimum temperature in the dry season (Peng et al. 2004). Numerous models developed to estimate the impact of climate change on rice yields have produced similar trends and conclusions (Parrya et al. 1999; 2004; Yao et al. 2007).

3. Cassava and Sago as the Staple Food of Indonesia

Table 2 shows that both cassava and sago have similar characteristics to rice, especially in terms of the carbohydrate and caloric contents, which are the only two properties that are important criteria for a staple food as a source of calories. Rice is greatly superior to cassava and sago only in its protein content. Based on these comparisons, it can be concluded that these food crops can partially or completely replace rice depending on their availability and acceptability.

Table 2. Nutritive value of carbohydrate commodity sources

Commodity	Content (%, dry basis)				Energy (Calorie)	Caloric ratio to rice
	Water	Carbohydrate	Protein	Fat		
Rice	12.0	80.00	7.00	0.50	359.70	1.00
Rice flour	13.0	90.69	7.82	0.80	401.26	1.12
Wheat flour	12.0	87.84	10.11	1.48	405.11	1.13
Fresh cassava	*59.4*	*92.92*	*1.71*	*0.49*	*157.00*	*0.44*
Cassava flour	*12.1*	*93.04*	*2.43*	*0.77*	*393.75*	*1.09*
Tapioca	*12.0*	*86.90*	*0.50*	*0.30*	*362.00*	*1.00*
Maize	24.0	83.68	10.39	4.47	416.58	1.16
Sweet potatoes	68.5	88.57	5.71	2.22	397.14	1.11
Potato	64.0	93.61	2.50	1.11	394.44	1.10
Sago starch	*14.7*	*98.49*	*0.82*	*0.23*	*353.00*	*0.98*

Compiled by Bantacut (2011) from multiple sources.

3.1. Cassava-Based Food Security

Cassava plants have many advantages: (i) cassava can grow in unfavourable conditions, such as acidic soils and extreme climates; (ii) it is productive in fertile soil but still capable of being produced in less fertile, infertile or marginal land; (iii) it has a long-range of harvest from 10 to 30 months; (iv) it is the world's largest staple food after wheat, rice and corn; (v) it is a significant source of carbohydrates; (vi) approximately 500 million people depend on cassava; and (vii) cassava has a sweet and bitter tuber (Laswai et al. 2006; Vessia 2008). This plant is known as the highest producer of carbohydrates among crop plants (ARC 2009) with daily energy production reaches 1045 kJ/hectare (Montagnac et al. 2009). Another factor is that cassava's potential to adapt well to climate change (Jarvis et al. 2012).

Cassava can be developed into a potential food crop. In addition to its productivity, it is high in calories and has an adequate nutritional content. The caloric content of the fresh roots (water content of 60%) is 157 calories, which is adequate for direct consumption as a staple food. This caloric content is increased with decreasing water content (dry), which facilitates handling and extends its shelf life. Cassava leaf is a good source of protein and vitamins (A, B and C), and it is an excellent source of vitamin C, containing 311 mg per 100 g (ARC 2009; Montagnac et al. 2009; Oni et al. 2010).

Traditionally, cassava has been used as a staple food in certain regions (mainly in Java), as illustrated by Suryana (2009) regarding the life of village communities in Cirendeu, Cimahi, West Java. Approximately 500 families consume tapioca solid waste (locally known as *onggok*). Their health is good, their average life expectancy is long and the elders are very healthy. It is difficult to find malnourished children under five; the boys are handsome, and the girls are beautiful. The villagers mix tapioca solid waste with a variety of food material, such as beans, cassava leaves and other available food sources, and they rotate crops to avoid food shortages. An example from Suryana indicates that replacing the main source of carbohydrates with cassava flour or tapioca would provide better food for better health.

Adaptation issues and habits become an obstacle to the use of cassava as a staple food throughout the nation. Zambia experienced failure in developing a cassava-based staple food source because of consumption habits (*i.e.*, familiarity) (Simwambana 2005). Good cooperation between the community and the cassava-processing industry may lead to more widely accepted uses of cassava. The following is a list of examples of processed cassava-based foods that can be provided in sufficient quantity and used as the main source of calories.

Nshima is the staple food of northern Zambia and consists of cassava mixed with cornstarch. Various methods of pre-mixing (pre-blending) are used to obtain the best preparation, and mutual cooperation between the processor (miller) and food makers (e.g., restaurants) allows these types of food to be obtained with relative ease.

Bread flour composite made from cassava flour and wheat is an adaptation measure and provides a reduction in the consumption of wheat flour. Zambian society has accepted this product and cannot distinguish the taste of processed foods using this flour (10-15% cassava flour) compared to wheat (PAM 2005).

Mixed flour can be added to fried foods, which are popular with the urban population in Zambia. The addition of up to 20% cassava flour to wheat is well accepted and reduces the consumption of vegetable oil, which is favoured by consumers.

Gari is a local food made from cassava flour, and after some modifications, improved composition and revised methods of preparation, there is a demand for this product.

The **sweetener** industry has developed sweeteners for use in the beverage industry and has increased the success of local companies developing alcoholic beverages from cassava. The sweetener industry has managed to significantly expand the use of industrial sweeteners (glucose syrup) to replace sugar in the beverage industry, which has encouraged farmers to increase cassava production.

These experiences demonstrate that a staple food may be replaced and become widely accepted by a community. Experimentation, modifications, socialization and community involvement are a precondition for the success of food adaptation. Research in Indonesia has revealed that the addition of cassava or tapioca (up to 50%) flour to wheat flour may be acceptable for certain processed foods, such as bakery items, noodles and muffins (Ratnaningsih et al. 2010). Recently, intensive research has been undertaken to develop a rice analogue (an artificial rice product made from non-rice and non-wheat raw materials by twin screw extruders) to produce rice-like carbohydrates from non-rice sources (Widara 2012) that have the same taste and benefits as original rice.

3.2. Sago-Based Food Security

Indonesia has the potential to produce approximately 60% of the worldwide yield of sago and provide an estimated total acreage of 1.2 million ha and production ranging from 8.4 to 13.6 million tons starch per year. Starch productivity could reach 25 tons/ha/year, which is the highest rate among starch crops (Ishizaki 1997), and in wild conditions, sago produces approximately 7-11 tons dry starch/ha/year, which is derived from harvesting of 40-60 trunk/ha/year with a pith weight of approximately one ton/rod and starch content of approximately 18.5%. The average productivity is 100-600 kg of starch/trunk, and dried starch productivity is approximately 10-15 tons/ha/year; this productivity is equivalent to that of sugarcane and much higher than that of cassava and potatoes. Sago starch consumption Indonesia is approximately 210,000 tons, which is 4-5% of the production potential. Many experts have predicted that in Indonesia, the use of sago forests would produce a carbohydrate benefit of approximately 5 million tons of starch (Flach, 1977).

The starch content of sago varies according to the variety and processing method. The industrial starch content must be at least 60%. The energy content of the starch is 353 kcal (compared with 360 kcal for rice and 405 kcal for wheat flour on a dry basis). In terms of carbohydrates, sago can be developed as a modern food with low-calorie healthy foods, and its nutritional value can be improved by adding protein and vitamins. Sago starch-based foods are also low in fat and thus are healthy for weight-conscious people. In addition to its wide use, the caloric content of sago indicates that it is a potential resource as a national staple food.

Traditionally, sago starch has been consumed by mixing hot water and stirring to form dough. The dough is then directly eaten with side dishes or further processed. Another preparation method is to form dough into a plate that is baked. Other ingredients (such as peanuts or grated coconut) may be added when mixing the plate such that the nutritional content is richer and the product tastes better. Coastal communities have used sago for a long time (Flach, 1977), and sago should be developed into a staple food for at least the coastal communities. The regions around Papua and Maluku could depend on sago as a staple food (Kanro et al. 2003) because of its high potential for production and the experiences of the communities in consuming sago.

Sago food products have many advantages compared with other commodities, which may provide greater benefits for certain groups and not others (Leong et al. 2007). The benefits and advantages of various foods, such as sago snacks or processed sago noodles, include the following: (i) sago has the effect of being filling at a lower caloric content; (ii) sago can prevent constipation and colon cancer risk; and (iii) sago does not quickly raise blood glucose levels (low glycaemic index), and thus, it can be consumed by people with diabetes mellitus (Karim et al. 2008). Traditional sago foods that are common and widely consumed are listed in Table 3.

The possibility of sago starch as a staple food is clear based on its composition, especially its carbohydrate composition, caloric content and use in traditional sago-based food. Table 2 provides a list of comparisons that show the potential and feasibility of sago in replacing rice as a staple food for the Indonesian population. However, for wider acceptance, additional processing efforts should be developed, such as the production of noodles, edible film, sago pearls, bread and biscuits.

Noodles are a (staple) food product that can be made from sago starch, and the starch quality of sago meets the required standards. The national production of vermicelli is still relatively low at 80,000 tons/year. The domestic and foreign demand continues to grow, although vermicelli made from sago starch has little competition.

Indonesia continues to import vermicelli (made from rice flour) from various countries (especially China) (Bank Indonesia 2007).

Edible films can be made from sago starch. The processing and mixing of suitable additional materials would produce excellent edible films. These coatings can be made from a variety of polysaccharides, proteins and lipids, and the advantages include biodegradability, edibility and biocompatibility as well as an attractive appearance and ability to resist oxidation and physical blemishes. Due to its biodegradable properties, starch is the most widely used raw material, and it is renewable, widely available, easy to manage and inexpensive (Lourdin et al. 1997). Edible films are designed to increase the consumer acceptance of sago food products. Products are wrapped in a more attractive and compact fashion so that they can maintain a consistency of shape and provide improved taste, aroma and flavour.

Table 3. Types of local food produced from sago

Local name	Origin	Preparation
Papeda	Maluku and Papua	Sago starch is stirred in cold water to form a suspension and then poured into hot water until thickened and discoloured. Stirring is stopped when the colour is evenly distributed.
Kapurung	South Sulawesi	Sago starch is stirred in cold water then thickened with hot water. Pasta is shaped into small spheres with bamboo chopsticks by rotating the pasta. Pasta is then mixed with fish, shrimp and vegetables.
Sagu lempeng	Papua and Maluku	Sago starch chunks are rubbed on a screen then sifted again to obtain fine starch, which is ready to be cooked. The starch is then cooked in a *forna* (cooking appliance in Maluku). Sago starch is placed in a forna that has been previously heated and is then covered with banana leaves for 15-20 minutes until cooked.
Buburnee	Maluku	Wet sago starch is made into crumbs and smoothed, such as in the preparation of the sago plate; grains are then made by shaking the starch above a clean surface. The granules are roasted in a crock until golden yellowish white or lightly browned.
Bagea	Maluku and Sulawesi	Sago starch is wrapped in banana leaves or sago leaves and then heated in a pot. To improve the nutritional value, sago starch is mixed with eggs, walnuts and salt.
Ongol-ongol	Maluku, Papua, Sulawesi, and West Java	The preparation is similar to papeda, but it is mixed with brown sugar.

Haryanto dan Pangloli (1992).

These examples show that sago is already consumed as a staple food in certain regions, and it can be further developed into a modern staple food for increased acceptability in a wider community. The existing food habit and menu should be considered such that newly developed foods are more easily and widely accepted. In addition, Barton (2011) has argued that the acceptance of rice as a staple food in Borneo (Kalimantan) was an illogical crop choice because rice cultivation is difficult and prone to failure, and yields are often low. In contrast, the people had access to sago palms, which is a better and more productive staple food resource that can be traced back to the era before the mid-Holocene.

4. Future Staple Food of Indonesia Population

The above discussion suggests that rice-based foods will be exposed to a high risk in the future. Technologically and socially, cassava and sago could potentially replace or accompany rice as a staple food for all Indonesian people. Staple foods should be sourced on the future production of non-rice carbohydrate material, especially cassava and sago. Therefore, potential selections should be further analyzed based on the requirements and availability of land for production and food development programs based on alternative staple food materials.

4.1. Land and Water Requirements

The determining factor in the capacity for food production is the availability of land for crops. A comparison of the demand for land necessary to produce sufficient food from different plants can be an important consideration and will become more meaningful in future situations of uncertainty based on climate change and increased competition for land use. Because of the enormous uncertainties surrounding global climate change, it is estimated that cropland reductions will be significant. It is important to note that global warming is likely to alter the production of rice, wheat, corn, soybeans and potatoes, which are staples for billions of people and major food crops in both North America and Africa. Table 4 shows a comparison of the land required for the production of the staple food for the people of Indonesia in 2030. Sago plants require less land than cassava, and rice requires nearly three times as much land as cassava. Moreover, the land and water availability requirements of cassava and sago are much simpler than for rice.

Table 4. Comparison of requirement parameters for food crop production in Indonesia

Parameter	Rice	Cassava[†]	Sago[‡]
Consumption (kg/capita/year)[1)]	130[x]	320[y]	135[z]
Productivity (ton/ha)[a]	3	40	25
Land requirement (ha/person/year)	0.043	0.008	0.0054
Current Indonesian population (million)	230	230	230
Total consumption (ton)	29,900,000	73,600,000	33,750,000
Total land requirement (ha)	9,890,000	1,840,000	1,350,000
Total land requirement (ha/year)	4,945,000 [b]	1,840,000[c]	1,350,000[d]
Indonesia population 2030 (million)	270	270	270
Total land requirement 2030 (ha)	5,805,000	2,160,000	1,584,000
Land characteristics	Fertile and irrigated	Marginal to fertile	Swamp and coastal
Land type	Mainly wetland (rice field)	Wet and dry lands	Wet land (swampy)
Water consumption	Very high	Low	High
Climate influence	Very high	Low	Low
Fertilizer use	Very high	Low	Low
Pest attack	Very high	Low	Low

[†]Bantacut (2010); [‡]Bantacut (2011)

Notes: [a]intensive cropping; [b]two planting seasons/year; [c]one planting/year; [d]harvest of 40 trunk/ha/year; [x]milled rice, [y]fresh cassava, [z]starch, [1)]This amount of consumption is based on the caloric equivalent i.e. rice, fresh cassava and sago starch respectively.

Wahyunto (2009) has estimated that the irrigated land is currently around 4.3 million ha out of a total of about 7 million hectares of rice fields. Land conversion occurs very quickly, for example Java experienced irrigated land conversion reduced area of 320 thousand hectares to 3.2 million hectares during 2000-2005. Tidal rice fields also decreased dramatically since it has been converted into shrimp farms and other uses. Likewise, in addition to reduced rain fed field area, farmer tend to cultivate their land with non-rice crops because of economics reasons. Overall, the reduction in rice area has been going quickly and massively that bring about rice field limitation in the near future.

Bappenas (2010) has suggested that in the medium term agricultural expansion would be constrained by several factors: (i) ownership status; (ii) administrative authority; (iii) the availability of labor; (iv) the availability of infrastructure for input procurement and distribution of farm output; and (v) spatial plans (land for residential development, urban and commercial uses, forest conservation, etc.). Consequently, out of 4 millions hectares suitable land for agriculture, approximately only 650 thousand hectares can be developed for expansion of rice field spread in Papua, Maluku, Sumatera, Kalimantan, and Sulawesi. Hikmatullah et al. (2002) have argued that agriculture expansion outside Jawa faces more constraints such as soil fertility and land topography. Bantacut (2012) has made a reasonable estimation of those land expansion productivity to be about 4 tons/ha and harvest index of 1.6, then the potential production through extension is about 4.2 million tons. Sumaryanto and Sudaryanto (2005) have warned, although the data is not entirely accurate, numerous researchers agreed that the rate of fertile rice field conversion is approximately 110,000 ha/year. Therefore, the extension of rice field to strengthen food security is not an easy task and does not necessarily ensure adequate national rice production.

This comparison shows that sago is the best option regarding the land area requirement, whereas cassava is the best option in terms of land quality and water requirements. Both sago and cassava require less fertilizer and maintenance than rice. The combination of both plants can meet the food needs of the future population of Indonesia because they are associated with relatively fewer climate disruptions and fewer pests. Therefore, the food security of Indonesia could be strengthened if food needs were based on these two commodities.

Based on potential climate change, it is expected that water shortages, water pollution, floods and pest attacks will worsen the situation of agricultural farming (see Bates et al. 2008; Ivey et al. 2004; Mukheibir 2010).

Therefore, sago and cassava should be selected as staple foods. Environmental pollution caused by fertilizers and pesticides will become a more significant issue in the near future (OECD 2012). Rice cultivation is based on intensive agriculture that requires massive amounts of fertilizer and pesticides. To date, efforts to reduce these applications have not been successful.

Rice as a semi aquatic plant requires water 450-700 mm/total growing period which is almost equivalent to other crops such as maize 500-800 and potato 500-700 for total growing season. The difference lies in the way as rice cultivation requires a lot of water to soak or wet the soil where they are grown. In addition, rice has some sensibility to water stress and some tolerance to water excess. Therefore, water condition of rice growing field is to be controlled to keep water supply under submergence condition for 100-110 days, usually eliminating the risk of water deficit. This means increase the need for water to be supplied to 1200-1460 mm in the entire growing season (Watanabe 1999).

In the context of Indonesia, high water requirement of rice would be a constraint to increase its production. Many researchers (such as Hidayat et al. 1996; Nasution and Syaifullah 2005; Nugroho and Tikno 2002) have warned a situation of water scarcity for rice production in 2030. Most rice producer centers in Jawa will experience water crisis (West Java: Indramayu, Karawang, Bekasi and Tangerang; Central Java: Demak and Bantul; East Java: Sidoarjo and Lamongan), and water difficulty (West Java: Cianjur, Ciamis, Majalengka, Sumedang; Central Java: Kudus, Pati, Rembang, Blora, Sragen, etc.; East Java: Sidoharjo, Jombang, Ngawi, Nganjuk, Trenggalek, etc.). Therefore, declining of the rice production potency is very clear in Indonesia. Take into account, rainfall and water availability, each region has a specific and relatively shorter growing season. For instance, in Banten Province, the growing periods vary between 140-180 days depending on rainfall and irrigation systems (Hidayat et al. 2006; Manik, 2009).

In the above circumstances, the paddy water requirement has not been much changed yet. A study in relatively rare population region in Kalimantan showed that water is not continuously available for the whole year, surplus in wet season and shortage in dry season (Haryanto et al. 2013). The situation is a more worsen in heavily populated region with massive economic activities, including in the irrigated paddy field supported with big dam (Surono, 2003).

4.2. Flour-Based Food

The above descriptions show that when compared with other commodities (especially rice), sago and cassava have the potential to be the main staple food of the Indonesian population. However, these advantages cannot eliminate the impression that sago and cassava are minor commodities compared to rice and wheat. A neutral comparison requires the conversion of all commodities to flour (or starch) such that the determinants are the properties, characteristics and value of their main components. Evidence suggests that the most successful diversification effort occurs with the introduction of wheat flour. In 2008, 6 million tons of wheat flour were imported; this figure has increased to a current value of approximately 7 million tons, which is a cause for concern. The depletion of the foreign exchange is not yet comparable to the long-term threat in which Indonesia does not obtain its import quota as a result of limited supply. When that occurs, it could cause social chaos and economic devastation.

The form of flour or starch facilitates further modification and processing, including fortification with various desirable nutrients and flavours. This form also facilitates and prolongs the storage period or product endurance for months and even years. On a practical level, this facilitates the transportation and processing into various types and forms of food according to individual tastes.

Industry has a significant opportunity to produce and process flour for the fulfilment of a staple food source that has a strong market and availability of raw material. Therefore, this industry can be further developed to break the cycle of rural poverty. In the context of rural development and agriculture, these efforts encourage a shift from subsistence farming with a traditional structure to more modern and commercial farming. Rural economies are expected to break away from the restraints imposed by the required improvements in agricultural productivity and income based on the creation of non-farm employment opportunities through the growth of small and medium enterprises (SMEs) (Rehber 1998). The flour industry is expected to integrate non-agricultural industry with agricultural activities to enable farmers to invest more in their farms (Galor 1998).

Accordingly, the flour industry can contribute to rural economies based on the number of process steps and operations located in rural communities and level of local community involvement. Therefore, effort should be focused on building as many stages of the process as possible, and such efforts are a fundamental principle of rural economic development. Optimization should be performed because the industry is constrained by technical and economical scales, and the number of stages and complexity should be adjusted according to the potential of the agro-industry and rural capacity.

5. Problems

There are certain barriers to the development of cassava and sago as staple foods, including sociological, psychological and physiological barriers. Socially, the consumption of sago is considered inappropriate because it is difficult to find and hard to prepare. However, this view can be changed through the development of flour or starch-based staple food products that are more attractive and easier to find. Adequate extension is expected to change such mind-sets and perceptions toward staple foods and all foodstuffs.

Similar to the sociological issues, it is psychologically difficult to accept “low-grade” food onto the main menu. This perception is also influenced by global insights in which limited amounts of cassava and sago are consumed. An expansion of consumption, increase in cassava and sago "degrees" through intensive and adequate promotion and the development of processing and better technology would be sufficient to change such views. These changes are also intended to facilitate the preparation and presentation of menus composed from a harmony of flavours, aromas, textures and customs of the population. Government of Indonesia has been very success to convert non rice eater into eating rice as the only staple food. Now, the government is requested to do the same trajectory to return and add more people to consume non-rice staple food, especially cassava and sago.

Physiologically, the body’s acceptance of new foods requires adequate adjustments and recognition. The consumption of the same amount of calories from different foodstuffs can lead to different filling effects. However, many people survive and grow by eating cassava and sago, indicating that this problem is temporary and requires practice to overcome any issues. The protein content of both cassava and sago is significantly lower than those of rice. Menu development should consider this limitation so protein intake could be maintained.

Such problems limit the utilization of the potential and high productivity of both commodities. Other influencing factors include the following (Bantacut 2010): (i) cultivation is not well developed, and thus, most of the commodities are derived from wild sago or undeveloped cassava plantations; (ii) most primary processing (extraction) is performed traditionally using simple equipment that is inefficient (Ellen 2008); (iii) utilization as a foodstuff remains undeveloped and requires a planned introduction and dissemination; and (iv) the potential market is untapped.

6. Conclusions and Recommendations

Climate change is an on-going process that will certainly disrupt food production, especially that of rice. Disruptions to rice plantations have been common and include droughts, floods and pest outbreaks. Such events will be even greater in the future; therefore, relying on rice as a single staple food is a risky proposition. Thus, staple food diversification is required to reduce the risk of hunger in the future, and cassava and sago are commodities that are relatively resistant to climate change disturbances.

Cassava and sago are commodities that have a huge potential to become staple foods and raw material for starch-based industries that are already well known and established in society. Such enormous potential should be utilised to increase Indonesian self-sufficiency related to food. The development of an integrated cassava and sago commodity will solve the problem of food security and sovereignty in a more sustainable manner and will make Indonesian food supplies extremely resistant to economic disruptions, farming challenges, climate change and natural disasters.

Research and development must be expanded to include additional food processing techniques that are more acceptable, feasible and practical to provide a menu that meets the tastes of the community at large. Therefore, the development of cassava and sago must be planned, programmed and integrated. Planning requires the establishment of clear step-by-step efforts to produce available commodities and processed products that are acceptable and marketable such that they create added value and contribute to the prosperity of the community.

Programming means that the role of the government is to not simply act as a regulator and facilitator; instead, it should be actively involved in driving the integrated and sustainable utilization of cassava and sago throughout the development process. The government has a significant responsibility in changing the perception of the staple food of rice to that of carbohydrates. It is expected that a change in the pattern of consumption will reduce rice demand, and the subsidies allocated to rice can be used to fund development programs for cassava and sago.

Integration is the key to developing cassava and sago in a technically and economically feasible manner. The upstream development (seeding, planting and starch production) should be connected to the downstream (market) requirements. Different criteria will determine the selection variety, and the processing and grading will be determined according to the final product. Such criteria must be associated with the use and development of downstream starch-based staple food menus that have a balanced nutritional composition and harmony of taste.

The establishment of a Cassava and Sago Research Centre (CSRC) has been suggested to resolve the above problems and for use as a strategic research and development center. The main activities of this institution would be the identification and characterization of plants and starch, the development of processing technology and products, the creation of suitable and acceptable menus and the socialization and introduction of new foodstuffs. This centre could be an independent institute or part of an existing university.

The introduction and promotion of new foodstuffs should be performed extensively by utilizing all media networks, including print, electronic or virtual media. Campaigns in mass media such as television, radio and newspapers should be initiated and encouraged. An agricultural talk show, which started in the last governmental administration, must be improved, and a focus on diversification would be significant for Indonesian independence and food sovereignty.

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