Chapter 6

Land Utilization Pattern in the Indonesian Forest: Cassava Cultivation in an Agroforestal System

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.76928

Abstract

The potential forestland for agroforestry implementation in Indonesia is teak forest (*Tectona grandis*). The teak forest is less dense during the dry season, allowing sunlight to enter through the trees gap to the ground under the canopy. Therefore, some people use that condition as "palawija" farming land (palawija/phaladwija, in Java-Indonesia represents the type of non-rice agricultural crops). It is done to prevent the growth of weeds that can disturb the teak growth. The phenomenon of land utilization under the stands (PLDT) is an alternative in accessing forestland use by the community, a part of intercropping location. Theoretically, if the implementation was correct, it could be an effort to restore the forest ecological function. The pattern of the PLDT model on teak forests needs to select correct plants according to temporal dynamics, namely the season (dry or rainy) and the plants age. Land use representation could be seen from the cultivation pattern and crops variety that is cultivated under the forest stands at three research locations called Development Areas wilayah pengembangan (WP). The palawija crops that exist on all three WP were cassava (*Manihot esculenta* Crantz).

Keywords: agroforestry, teak forest, land utilization under the stands, intercropping, cassava

1. Introduction

Forestland intentional use for agriculture which combines some types of plants (trees and shrubs with crops or forage) is commonly called agroforestry [1–3]. In Indonesia, it is called "tumpangsari/wanatani," which is a type of land use pattern in forest, which combines forest and agriculture components (woody plants and annual crops) at the same time. The potential forestland for agroforestry implementation is teak forest (*Tectona grandis*). It is one of the seasonal tropic forests, which is growing with the turn of the season (dry and rainy season). The teak forest is less dense during the dry season that allows sunlight to enter through the trees gap to the ground under the stands. Some people use that condition as "palawija" farming land (palawija/phaladwija, in Java-Indonesia represents the type of non-rice agricultural crops). It is done to prevent the growth of weeds that can disturb the teak growth.

The teak forests often form naturally due to the monsoon climate widely spread in the Northern Limestone Mountains, Kendeng Mountains and Muria Mountain. They also exist in Madura, Bali, Lampung (Sumatra), Flores (Nusa Tenggara Timur), Muna and some islands in Southeast Sulawesi. According to Banowati [4], the type of Javanese Teak forest spreads in Central Java and East Java Province. It can grow at an area up to an altitude of 200–650 m above sea level, with rainfalls of 1500–2000 mm per year and a temperature of 27–36°C, also dry months between 2 and 4 months. The best location for the teak growth is on soil with pH 4.5–7 that is not flooded with water (**Table 1**). The distribution of teak trees forms a tropical homogeneous forest in the limestone areas of Batang, Rembang, Blora, Grobogan, and Pati (Appendix 1).

The Indonesian teak forest is managed by the National Company of Forestry (Perum Perhutani) covering an area of 2.4 million hectares, consisting of protected forests (0.69 million hectares) and more than 1.72 million hectares (75.8%) as production forests. The extent of production forests allows the application of agroforestry patterns through Community Based Forest Resource Management pengelolaan hutan bersama masyarakat (PHBM) and the Land Use Model Under Stands pemanfaatan lahan di bawah tegakan (PLDT) program. The PLDT model is meaningful, especially in Java Island, because the people who live around the forests need farming land, which become narrower triggered by high population growth. Since 2001, the National Company of Forestry implemented the Community Based Forest Resource Management (PHBM). The PHBM paradigm was updated because it originally only prioritized the wood production, while using the word "forest," and changed to "forest resources."

Research location (village/plot)	**Soil: solvent used**			**pH**	**Temp. (%)**	**Elevation (m)**	**Slope (%)**
	Aα Bifiridil	**H_2O_2**	**HCl**				
I. Gesengan	No color changed	No froth	Many froths				
a. Plot 100				6.8	32°C/66	67	5
b. Plot 102				6.5	30°C/67	62	5
c. Plot 103				6.5	30°C/67	62	5
II. Semirejo	No color changed	No froth	Many froths				
a. Plot 114				6.8	29°C/72	138	16
b. Plot 115				6.6	30°C/67	137	10
III. Regaloh	No color changed	No froth	Many froths				
a. Plot 130				6.7	30°C/67	135	5
b. Plot 131				6.7	30°C/67	135	5

Source: [4].

Table 1. Physical measurements at the research locations in October 2016.

http://dx.doi.org/10.5772/intechopen.76928

Through this program, the forest surrounding communities have the right to work the land with each covering area of 0.25–0.5 hectares as intercropping area to support the workers' economic activities and to maintain the ecological sustainability of the forest. They were coordinated in the institution of village forest community lembaga masyarakat desa hutan (LMDH).

Forestland has relatively more fertile soil because it can naturally conserve the soil fertility through the closed system of nutrient cycle. The nutrients used for growth can restore fertility into the soil through the fallen leaves, twigs and branches [5]. Forests are land cover that refers as a place of vegetation, which is influenced by soil type, as in the research location located in Muria Forest Area kawasan hutan muria (KHM) and spreaded on Volkan Muria landform. It consists of Red Yellow, Mediterranean and Latosol [6]. According to Nursanti [7], Latosol is a soil which has eroded intensively, acid reacted and washed strongly, especially for K, Ca, and Mg bases. Latosol soil type has a medium fertility level, and for agricultural cultivation, it lacks P nutrient due to fixation by kaolinite clay minerals and Fe ions. Moreover, it lacks Al ions due to the low pH level. However, with intensive soil management, Latosol soil fertility can be improved by planting long-term vegetation (forests) so that the nutrient availability could be increased.

The phenomenon of land utilization under stands (PLDT) is an alternative in accessing forestland use by the community, a part of intercropping location. In the beginning, the PLDT implementation by the forest surrounding community was done without a legal procedure. Theoretically, if the implementation was correct, it could be an effort to restore the forest ecological function. The correct concept of ecosystem in a tropical land cover area is the leaf type of grass, shrub and tree canopy (forest stands). The PLDT activity could control the growth potential of reed, which could be harmful for the soil. Without owning land, there is no certainty for the villagers (farmers) to meet the needs of their family members. Palawija could act as forest floor plant, which potentially helps in hampering the erosion rate improving the quality of land by plants that have root nodules that fix the nitrogen (N). The types and varieties of palawija crops were adjusted to the standing of biophysical condition, which refers to the concept of crop rotation, in order to form natural formations both vertically and horizontally. The plants formation in teak forests requires ecological engineering in line with silviculture principles in conserving forest resources to treat forests properly and control their structure and growth without jeopardizing their production capacity [4, 6–11].

The pattern of the PLDT model on teak forests needs to select correct plants according to the temporal dynamics, namely the season (dry or rainy) and the plants' age. Selection of cropping patterns and types of food crops needs to consider the difference of plant canopy density as described in [11] classified as dense enough (40–70%) and rare (less than 40%). These were the best spots to efficiently utilize and fulfill the requirements for sunlight, water and mineral nutrients. Furthermore, based on [12], the amount of sunlight that escapes through the canopy between November and December was 4.47–14.85% of the open light. It could reach the forest floor and could be harmful for the teak stands growth. In addition, it is necessary to note that the physical condition of the land must be measured and analyzed to determine the accurate planting patterns and select the correct plants.

Land use representation could be seen from the cultivation pattern and crops varieties that were cultivated under the forest stands at three research locations called Development Areas

(WP). The palawija crops that exist on all three WPs was cassava (*Manihot esculenta*) with different proportions.

2. The land use pattern under teak stands

The land use pattern under the stands at the first WP was monoculture planting pattern used in the intercropping system with cassava (*Manihot esculenta*) crops as the main crop. However, the pattern at the second and third WP was polyculture planting pattern used as compound system with cassava crops that were less than peanuts (*Arachis hypogaea*). Cassava planting on Latosol soils was not recommended because it was susceptible to P nutrient deficiency due to fixation by kaolinite clay minerals and Fe and Al ions due to low pH level. If the cassava cultivation was continuously done without proper soil maintenance or crops rotation, it could decrease the soil condition and the land potential.

The cassava crop as monoculture pattern at the research location was well grown. Farmers chose UJ-5 varieties of cassava (*Cassesart*) and *Margona* in other locations. They utilized post-harvest teak forestland as well as between the young teak stands. In **Figure 1**, the cassava crops have dense fresh green leaves, which indicated the young age (±4 months).

Land use in the second WP was polyculture cultivation pattern used as mix cropping system. It is a plant cultivation system, which mixes more than one crop at the same land and time. The land distribution for cropping system was unregulated without regarding the space between. This simplicity was based on farmers/community understanding that the forestland is fertile, and whatever was planted would be fruitful. Crops varieties including peanut and corn (*Zea mays*) are used as daily food needs, and the yield surplus is sold at the local market (**Figure 2**).

Farmers have learned to manage the land from the nature, which provided technical mind of local knowledge. It could be seen from the terrace that was built to manage the water supply and to overcome erosion rate that is caused by the agriculture land use (seasonal). It was built across the contour in an angle of 135°.

Figure 1. Monoculture of cassava crops at the post-harvest teak forest.

Figure 2. Mixed cropping system adapted to the land physical condition.

At the third WP, farmers have utilized farmland for agriculture using polyculture compound systems, and the main crop was the peanut. It was chosen related to its roots' ability to produce N element inside the soil that could be useful for Murbei (*Morus*) plants which has been cut down. The N element could help the Murbei growth immediately and produce quality and leafy leaves. Corn plants cropping as boundary plants showed more natural characteristics compared to non-plant boundaries. This local knowledge at the third WP can be seen in **Figure 3**.

Based on **Figures 1–3**, they indicate that the land use at the first WP is more oriented to economic aspects. The land use results meet the needs of tapioca flour industry. Different results at the second WP reflect more prioritized ecological aspects, while the farmland utilization at the third WP was a combination of economic and ecological aspects. Cassava was chosen as seasonal plants for agroforestry because it has the ability to stand against pests, have a simple vegetative breeding,

Figure 3. Compound system dominated by peanut.

and relatively stable price and the existence of tapioca flour industry as one of permanent stakeholder, which receives the cassava yield. The cassava cultivation was done throughout the year. The *Margona* variety has a planting age of 8–9 months, while the *Cassesart* was planted since 2014.

3. Cassava planting under the teak stands

Agricultural plants varieties which were cultivated at PLDT plots were cassava (*Manihot esculenta*), peanut (*Arachis hypogaea*), corn (*Zea mays*) and long beans (*Vigna unguiculata* ssp. *sesquipedalis*). Among the four crops, the cassava was cultivated in all WPs although the proportions were different, the other crops were only cultivated at the second and third WP. Some considerations of these diversities selection were influenced by the habit and general knowledge of the community. They were considered whether the plant could damage the environment or vice versa. They considered that cultivated land is better than empty land. On a wide scale, the third WP condition was in line with [13] which was done at a mountain village in Aga Khan, Pakistan. There was a tendency of harmonious relationship between the sustainability of biodiversity in a village and the community. There was no barrier for accessing the biodiversity. Development was succeeding to synergize economic and ecological functions. This condition could be followed by the first WP and become a consideration matter for the Government in determining the public policy related to the control of the state forestland, especially when distributed at the mountainous area.

Farmers cultivate cassava continuously and routinely, but the result was decreasing slowly because the farmlands was lacking of nutrients, which affected their productivity and cassava's quality, determining a low price, as well. The suggestion to not cultivate cassava in forestland was neglected by farmers for several reasons, that is, (1) financial limit to buy seeds, while for the cassava, it only needs the stem cutting, (2) the farmers are not brave enough to speculate on other plants; (3) worries about crops failure, while it needs high cost of maintenance, fertilizers and pesticides, (4) ease of cassava marketing, which is supported by the tapioca flour industry existence, and (5) simple method of cropping system.

Cassava planting was done by placing the stem at a depth of approximately 5 cm. The spacing of 9 × 9 cm produces 11,200 cassava trees per hectare. Weeds cleaning was done by cleaning the grasses without using pesticides and only once in each cropping cycle. Fertilization activities were done twice in each cropping cycle, at the beginning of the planting and at the third or fourth month after. Replanting process in this study was done when the cassava plants had too many buds, and if it was still in a reasonable condition, the farmer did not do it. The last activity was harvesting by removing the cassava trees at 9–12 months' age, depending on the seed used.

Based on the interpretation of SPOT 6 satellite image acquired in 2014, it was known that the cassava farmland distribution was on the north part of Muria Volcano, which 83.7% laid on the high slopes. It covered the Tlogowungu, Margoyoso, Cluwak, Gembong, Margorejo and Tayu districts. Meanwhile, 16.3% was on the south, which is the north part of Kendeng Mountain, including Sukolilo, Kayen and Tambakromo districts (**Figure 4**).

The actual area of cassava in 2014 was 18,544 ha, but the productive one was only 96.37% (17,871 ha) (**Table 2**). The total production of wet cassava and its cover was 744,746 tons [15].

http://dx.doi.org/10.5772/intechopen.76928

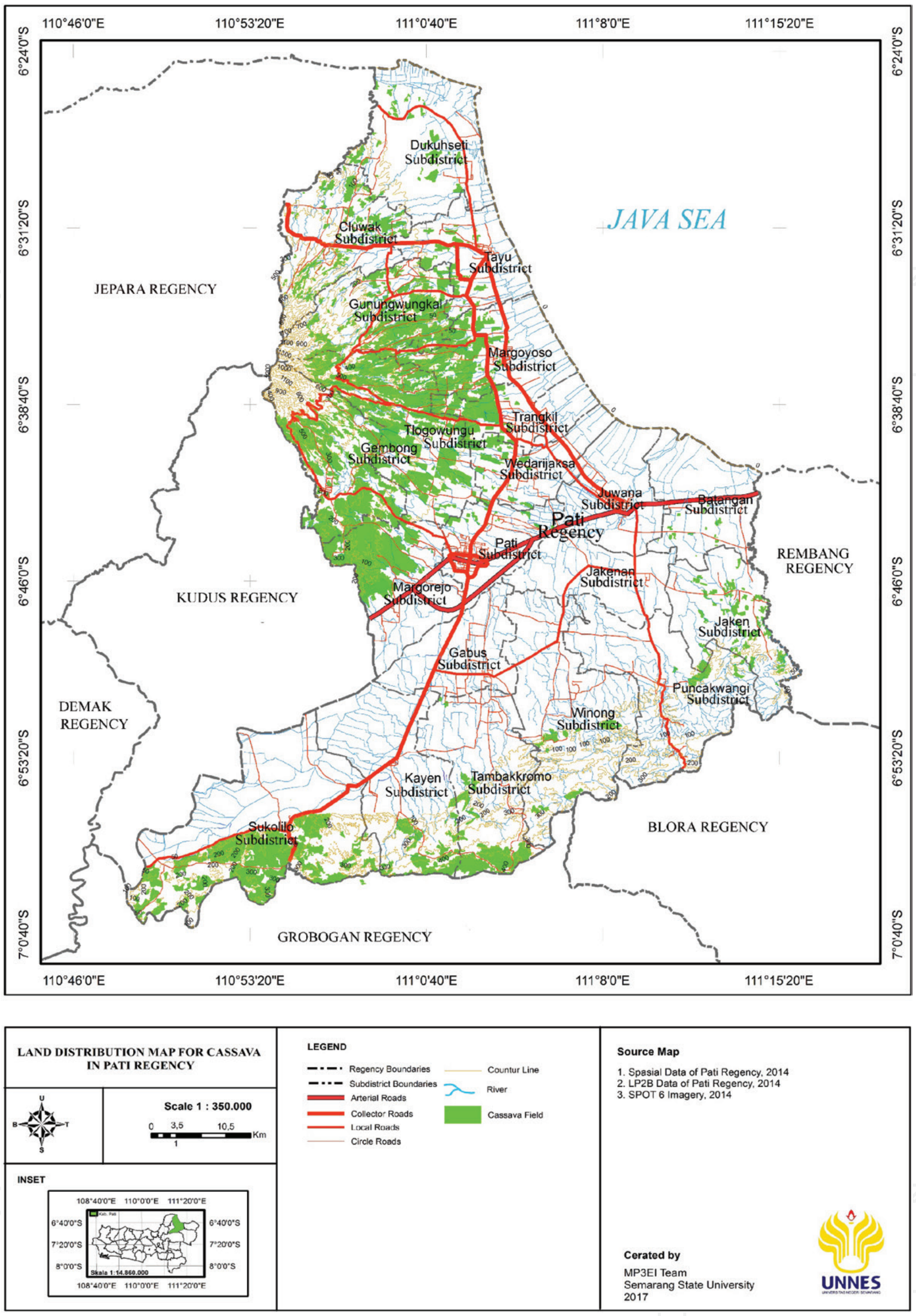

Figure 4. Map of cassava farming distribution in Pati Regency/east slope of Muria Forest. (Source: Spatial data of Pati Regency, 2014; LP2B data of Pati Regency, 2014; SPOT 6 imagery, 2014).

Nevertheless, tapioca processing industry did not run optimally due to instability of raw material supply of cassava because of several causes. On the one hand, one cause was farmer's reluctance because of the cassava price declining in the last 2 years (2014 and 2015). On the other hand, another cause was the farmer's side problem, including the reducing of farmer's land tenure, limited access to capital/financial support, non-innovative technologies to manage land and to process yields. Therefore, it is required to optimize farming productivity in terms of supply, demand and price fluctuations.

No	Year	Harvest area (ha)	Total production (ton)	Average production (ton ha^{-1})
1	2015	15,200	661,976	43.55
2	2014	17,871	744,746	41.67
3	2013	16,163	695,460	43.03
4	2012	19,696	732,961	37.21
5	2011	17,431	532,874	30.37
6	2010	21,989	643,558	29.27
7	2009	16,994	386,434	22.70
8	2008	16,740	318,194	19.00

Source: [14].

Table 2. Cassava production in Muria forest of Pati Regency.

Based on analysis result of spatial distribution pattern in **Figure 4**, it was shown that regional distribution index (Moran's Index) has influenced the production and supply continuity, also the transportation factors in terms of cost, distance and travel time (**Table 3**).

L value comes from the total number of joint areas; for example, in Tlogowungu district, the L value was 6, which means that the district is bordering to another six districts. The x value was 4283, which means that the total area of cassava farming land in that area was 4283 ha. While the L value of Pati District was 6), it means that transportation of yields was easy but the total area of cassava farming land was only 16 ha. Based on calculation result, it was found that the total joint area was 63 (**Table 3**). Calculation result determined the index of spatial distribution pattern using formula (1):

$$I = \frac{n \sum_{(c)} (x_i - \bar{x})(x_j - \bar{x})}{J \sum_{(c)} (x - \bar{x})} \quad (1)$$

$$I = \frac{18 \text{ x } 369407.9544}{63 \text{ x } 27753220}$$

$$I = \frac{6649343.179}{1748452.860} \quad I = 0.0038$$

Based on the formula, a positive I value of 0.0038 was obtained, which means that the cassava farming land distribution pattern in Pati Regency was clustered. This condition could facilitate the cassava yield transport to the local market and to collectors or brokers who supply the tapioca industry.

Referring to serial data of BPS Pati Regency, the cassava production in 2012 increased with 27.3% of total harvest area of 19,696 ha. However, it showed a declining trend pattern due to the decreasing cultivation area of about 9.27% (in 2014), and by 2015, the farming land decreased with 14.95% (15,200 ha of cropland). This affected the cassava production to 661,976

No	District	L	L^2	Region Value		
				(x)	$(x - \bar{x})$	$(x - \bar{x})^2$
1	Tlogowungu	6	36	4.283	3.417	11675.889
2	Gembong	2	4	3.276	2.410	5808.100
3	Cluwak	3	9	2.427	1.561	2436.721
4	Gunungwungkal	5	25	1.400	534	285.156
5	Margoyoso	4	16	1.097	231	53.361
6	Margorejo	4	16	1.638	772	595.984
7	Trangkil	3	9	537	−329	108.241
8	Dukuhseti	2	4	110	−756	571.536
9	Tayu	4	16	301	−565	319.225
10	Sukolilo	1	1	115	−751	564.001
11	Jaken	3	9	72	−794	630.436
12	Winong	4	16	51	−815	664.225
13	Tambakromo	3	9	51	−815	664.225
14	Kayen	3	9	63	−803	644.809
15	Wedarijaksa	4	16	85	−781	609.961
16	Pati	6	36	16	−850	722.500
17	Pucakwangi	3	9	53	−813	660.969
18	Batangan	3	9	7	−859	737.881
Total area join		63	249	15.582		27753.220
Rata-rata				866		

Source: ([14]); Secondary Data Analysis, 2017.
Information:
L = number of joint area.
x = total area of cassava farming land in each district.

Table 3. Spatial distribution pattern of cassava farming land (joint area analysis).

tons or 231691.6 tons of wet tapioca. Lack of cassava yields was overcome by supplying from other regions yields. At national scale, the total imports from January to April 2017 reached 1234 tons. Import of cassava was done to meet the need for less supply positions, which was triggered by the relatively low price of cassava. Therefore, farmers might switch to cultivate other crops (**Figure 5**).

Cassava supply from farmers tends to decline since 2014 as a result of farmer reaction who did not want to cultivate their land and delay the harvest time. This made the cassava market price to decline up to 44.6%. Tapioca industries did not produce optimally, but tapioca imports conducted by the Ministry of Trade, up to June were more than 1 million tons/year [14]. Domestic industries that use tapioca flour prefer imported tapioca flour due to cheaper price, better quality and continuous supply assurance [16]. However, the Ministry of Agriculture had cassava

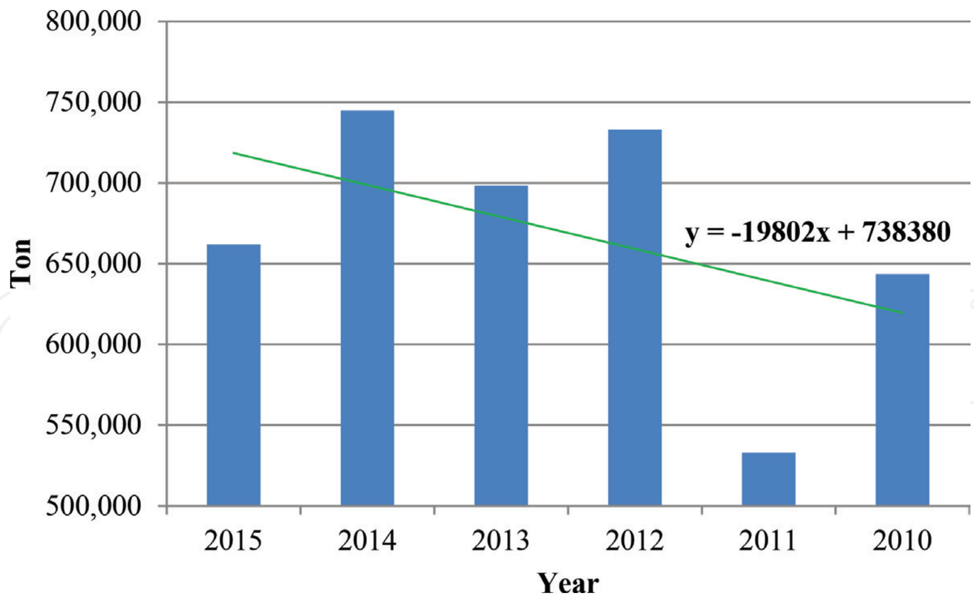

Figure 5. Trend of cassava production in Pati Regency. (Source: [14]; Secondary Data Analysis, 2017).

production data of local farmers, which are more than enough to meet local market needs. At national scale, other causes of imports are not influenced by lack of cassava production, but according to [16–19], not all cassava production meets the proper quality standard of Hazard Analysis Critical Control Point Specification (HACCP).

The highest production of cassava at national scale was in 2012, then decreased in years after. Different phenomenon occurred as compared to the production stability in Pati Regency, although the production decreased in 2015 as the effect of cassava price declining in the market. The cassava of Pati Regency contribution to food availability could be categorized in two levels, namely national and province scale (**Figure 6**).

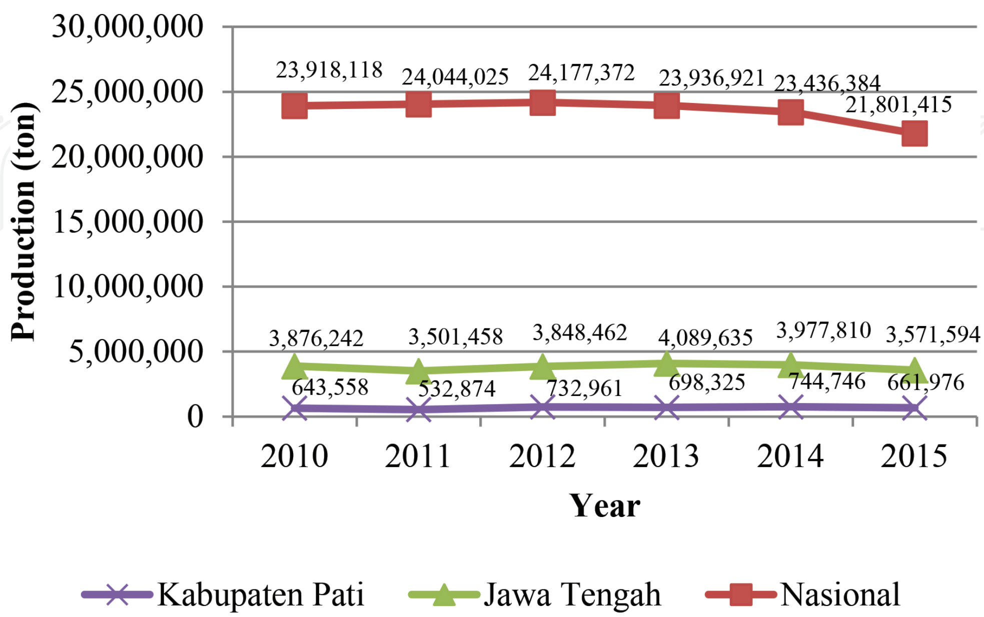

Figure 6. National cassava production in 2010–2015 (Source: [14]; Secondary Data Analysis, 2017).

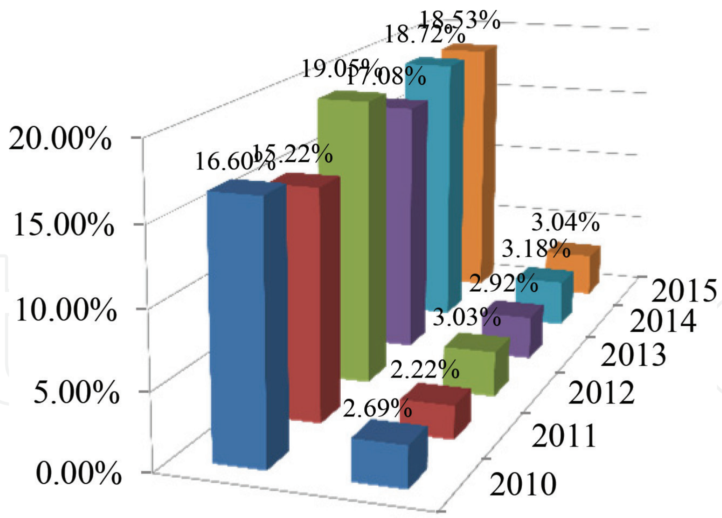

Figure 7. Contribution of cassava production quantity in Pati Regency. (Source: [14]; Secondary Data Analysis, 2017).

From these data, the contributions of 2010–2015 tend to increase, which were supported by the quality of human resources in the management of natural resources effectively and efficiently through appropriate technology utilization for determining the amount of productivity.

Therefore, it could be seen that the revitalization of tapioca industry had potential availability to meet the food demand for tapioca, which was supported by the increased production of agro-industrial areas in Pati Regency. It can be possible to be applied in other location/area considering that there still exists productive cassava farming lands at regional and national scale (**Figure 7**).

The presentation of BPS data for the last 5 years was an inventory of land resources and cassava production of certain years that were distributed all over Indonesia. It can facilitate the management of land and the use of cassava as raw material for food industry and as a crop that is easy to be cultivated. In this context, data in **Table 4** represent the existing land requirement to know the location and position for planning and direction of infrastructure development related to trade accessibility (transportation and or modes of transportation) of

Year	National		Central Java Province		Pati Regency	
	Area (ha)	Production (ton)	Area (ha)	Production (ton)	Area (ha)	Production (ton)
2010	1,183,047	23,918,118	188,080	3,876,242	21,989	643,558
2011	1,184,696	24,044,025	173,195	3,501,458	17,431	532,874
2012	1,129,688	24,177,372	176,849	3,848,462	19,696	732,961
2013	1,065,752	23,936,921	161,783	4,089,635	16,163	698,325
2014	1,149,208	23,436,384	153,201	3,977,810	17,871	744,746
2015	949,253	21,801,415	150,874	3,571,594	15,200	661,976

Source: [14, 15, 20].

Table 4. Production and cultivated areas of cassava in Indonesia.

cassava yields to industry or market. According to [21, 22], farming land has a strategic function as basic resources in land-based farming. Determination of infestation strategy based on geographical condition could illustrate the potential of a region (**Table 5**).

No	Regency/municipal	Area (ha)			Difference associative
		Normative source (BPS)		Productive	
		Regency	Province	Correction	
1	Banjarnegara	8400	8400	6403.17	−1996.83
2	Banyumas	2987	2987	1540.17	−1446.83
3	Batang	1825	1825	1791.62	−1666.62
4	Blora	2482	2482	3340.92	+858.92
5	Boyolali	5057	5057	6710.78	+1653.78
6	Brebes	1872	1872	1198.03	−673.97
7	Cilacap	4413	4381	3159.81	−1237.19
8	Demak	428	428	952.83	+524.83
9	Grobogan	1241	1272	964.38	+292.12
10	Jepara	9073	9073	8841.35	−231.65
11	Karanganyar	4324	4324	539.19	−3784.81
12	Kebumen	5436	5436	1188.45	−4247.55
13	Kendal	571	694	6121.51	5489.01
14	Klaten	704	698	6312.83	5611.83
15	Kudus	1263	1488	5801.41	4425.91
16	Magelang Regency	2070	2070	3328.18	1258.18
17	Pati	18,544	17,871	15114.17	−3093.33
18	Pekalongan	8383	504	3286.01	1157.49
19	Pemalang	1401	1415	1576.35	528.35
20	Purbalingga	3291	3304	2232.24	−1065.26
21	Purworejo	5485	5489	267.42	−5217
22	Rembang	4815	4815	775.65	4039.35
23	Salatiga	180	180	73.80	−106.2
24	Semarang Regency	1812	1822	2177.68	−342.32
25	Semarang Municipal	9318	420	3312.16	−1156.84
26	Sragen	2491	2491	483.91	−2007.09
27	Sukoharjo	1600	1600	204.83	−1395.17
28	Tegal Regency	501	517	7573.40	7064.4
29	Tegal Municipal	0	0	78.53	−78.53
30	Temanggung	1739	1739	2289.21	−51105.79

No	Regency/municipal	Area (ha)			Difference associative
		Normative source (BPS)		Productive	
		Regency	Province	Correction	
31	Wonogiri	51,656	51,656	24761.21	−26894.79
32	Wonosobo	6880	6880	382.66	−6497.34
33	Magelang Municipal	24	2	0.83	12.17
Total		170,266	153,192	122784.71	−38944.78

Source: [14, 23]; Geometric Corrections, 2017.

Table 5. Normative and productive cassava farming land in Central Java Province.

Secondary data analysis on cassava farming land area in this research, based on statistic data of BPS (Regency), showed that the normative area was 170,266 ha or in other words there was a difference in the total of 17,074 ha if compared to data source of BPS (Province) in total 153,192 ha. While the result of geometric corrections used as a sampling method showed that the productive farming land was 122784.71 ha or it was less with 38944.78 ha of normative area. The dynamics of land use had a significant effect on the production size and quantity, as well as on population and economic growth in the area.

4. Conclusions

The land existence as a sustainable resource is closely linked to the living space and surrounding of natural environments, which is influenced by the effects of weather and climate (sunlight, rainfall, wind, erosion, climate change, etc.). The intensity of land use under the forest stands could be known from the cropping pattern, which is conducted in units of a cycle time. The cropping pattern in this research was a sequence or a combination of cropping systems that were analyzed in terms of spatial and temporal dimensions on a land plot. Intensification of land use under the stands was fitted to the age of the stands, season and type of crops. The appropriate cropping pattern with biophysical conditions of Pati Regency was the intercropping on the stands that have more than 10 years old and monoculture on the stands that have less than 10 years old. Diversification of both cropping patterns requires the harmonization efforts between the shade effect and characteristics of the agricultural crops. Productivity of the crops was equivalent to 75% of land without shade and 50% of land with shade.

Acknowledgements

This chapter was written based on result of National Strategic and research grant on scheme of Masterplan Economic Development Acceleration and Expansion of Indonesia (MP3EI), which was funded by the Directorate of Research and Community Service (DRPM), Ministry of Research, Technology and Higher Education of Indonesia.

Thanks to: Director of Research and Community Service, General Director of Research and Development, Rector of Universitas Negeri Semarang (UNNES), Chairman of Research and Community Service Institute of UNNES, Dean of Faculty of Social Sciences of UNNES, Head of Forest Resources Bureau (Perhutani) Unit I of Central Java and all farmers (*pesanggem*) of Muria Forest who have supported and worked together to support this research.

Conflict of interest

I declare that I have no conflict of interest within this research or this manuscript.

A. Appendix 1

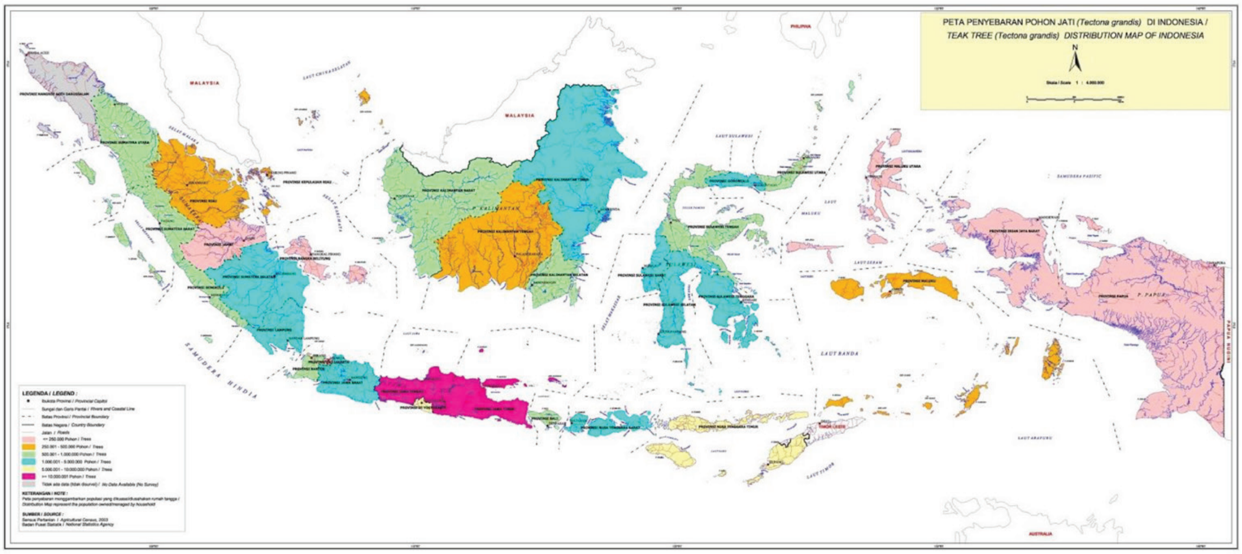

Figure. Teak tree distribution map of Indonesia (Source: webgis.dephut.go.id).

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