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Research Article

The impact of land use change on land capability in Tirtomoyo-Wonogiri

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Abstract: This research was conducted with the aim of studying land use change and evaluating the impact of land conversion on land capability in Tirtomoyo District of Wonogiri Regency. This research employed a descriptive, explorative method by utilizing SIG Arc Map 10.1 and Google Earth Pro software. The analysis of land use change, especially agricultural land, was conducted through visual interpretation of Google Earth Pro satellite imaging in 2004 and 2016. A ground check was done by land survey. Soil sample analysis was done to determine land capability class. Based on research results, it was found that eight locations experienced land use change. Location 1 had changed from secondary forest to moor, location 2 from moor into farm, location 3 from bushes into paddy field, location 4 from paddy field into farm, location 5 from paddy field into farm, location 6 from moor into paddy field, location 7 bushes into moor, and the location 8 from paddy field into farm. Land use changes showed different results of changes in soil physical properties based on soil characteristics at each type of land use. Changes in land use generally had less impact on land use class change. Locations 1, 6, and 7 did not experience changes in land capability class, but there were changes in the sub-classes of land capability. Locations 2 and 8 did not experience changes in class or sub-classes of land capability but sites 3, 4, and 5 indicated changes in land capability class by inhibiting factors namely permeability class in a paddy field.

***Keywords**: google earth pro, land capability, land use change*

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Introduction

Agricultural lands such as paddy fields or plantations have a significant role in the effort of maintaining food security. However, as the population and economic demands increase, the existence of food production lands begin to be jeopardized (Fitriyana, 2016). The high commodity selling value and the low land management lead to changes to other land uses. Land use change does not always mean the change from agricultural land to non-agricultural land but can also mean the conversion from forest land to agricultural land or plantation land to agricultural land. The changes in agricultural land use and the opening of agricultural lands should take into account the aspects of environment/topography, and proper land management such as soil cultivation, planting, maintenance, and harvesting cultivated crops. Junedi (2010) revealed that the conversion of forest to agricultural land causes changes in the physical properties of Ultisols, including decreased porosity, permeability, rapid drainage pores, and increased soil volume. The changes in agricultural land use also cause production declined of agricultural commodities such as rice production (Basuki et al., 2010).

Tirtomoyo sub-district lies at 111°0'14,319"-111°8'57,387" East Longitude and 7°54'31,447 - 8°0'54,032 South Latitude, Central Java Province, Indonesia. The altitude of this place ranges from

150-1112.5 m above sea level. Tirtomoyo District covers an area of 10,409.64 ha, consisting of 1,806.17 ha of paddy fields, 3,293.05 ha of moorlands, 2,402.55 ha of settlements, 1,572.39 ha of state forests, 56.20 ha of grassland, and 170.74 ha of other land uses. The types of land use in Tirtomoyo District in 2014 were 19.42% of paddy fields, 35.4% of moorland, 25.83% of settlement, 16.91% of state forest, and 0.6% of grassland (Central Bureau of Statistics of Wonogiri Regency, 2014). Based on the data from Central Bureau of Statistics of Wonogiri Regency (2015), there was a decrease in upland paddy field area from 820 ha (2005) to 274 ha (2014). The changes were dominated by the conversion of paddy fields to CGPRT (coarse grains, pulses, roots, and tuber) plantations, settlements, and other plantations. This shows changes in the cultivation level on the land. Tirtomoyo District has a landscape dominated by volcanic hills, volcanic mountains and alluvial plains in the central part of the region.

Each land use has different cultivation level; thus changes in land function can be reviewed by land capability classification to assess the optimization of the land that can ultimately be a capability assessment of the related land. Land Capability Assessment examines land according to its long-term productive capability. Class 1 soil is suitable for agriculture, while classes 7 or 8 are more suitable for conservation (Environment Southland 2014. Mondal and Mondal (2015) argued that land capacity depends not only on geomorphic parameters and soil fertility but also on technology inputs and management practices. Based on land use change and geographical condition of Tirtomoyo District which is dominated by a mountainous area, the research was conducted to evaluate the impact of land conversion on land capability in Tirtomoyo District of Wonogiri Regency. There had not been any research that studied the effect of land use change on land capability classes based on GIS (Geographic Information System).

Materials and Methods

Source of data and data collection method

This research was conducted in Tirtomoyo District of Wonogiri Regency, Central Java. The study was conducted from October 2016 to January 2017. The analysis of land use change was performed through visual interpretation (manually) on any past 12 years land use change on Google Earth Pro imaging with image retrieval times in 2004 and 2016. The use of Google Earth Pro software facilitates more precise results of vegetation interpretation when compared to Landsat imaging interpretation. According to Thoha (2008), standard multispectral classification based on 20-30 meters spatial resolution such as Landsat and SPOT are often considered less subtle for the study of agricultural and urban areas in Java. Soil sampling at each location was divided based on the result of satellite imaging visual interpretation, namely the lands undergoing land use changes in 2004 to 2016 and lands that had not experienced any land use change (control point/baseline). The physical properties and soil morphology observed were slope, erosion sensitivity, erosion level, soil depth, upper and lower soil texture, permeability, drainage, gravel, flood threat, and salinity.

Data analysis

The land use classifications were determined using the USDA classification system (Arsyad, 2005). To determine the capability class, matching method between land characteristics with the criteria of land capability class was conducted as presented in Table 1.

Table 1. Criteria of land capability class classification

Limiting / Inhibiting Factors	**Land Capability Class**							
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Surface Slope	I_0	I_1	I_2	I_3	I_0	I_4	I_5	I_6
Erosion Sensitivity	KE_1,KE_2	KE_3	KE_4,KE_5	KE_6	(*)	(*)	(*)	(*)
Erosion Level	e_0	e_1	e_2	e_3	(**)	e_4	e_5	(*)
Soil Depth	k_0	k_1	k_2	k_3	(*)	(*)	(*)	(*)
Upper Layer Texture	t_1, t_2 ,t_3	t_1, t_2 ,t_3	t_1,t_2,t_3,t_4	t_1,t_2,t_3,t_4	(*)	t_1,t_2,t_3,t_4	t_1,t_2,t_3,t_4	t_5
Lower Layer Texture	t_1, t_2 ,t_3	t_1, t_2 ,t_3	t_1,t_2,t_3,t_4	t_1,t_2,t_3,t_4	(*)	t_1,t_2,t_3,t_4	t_1,t_2,t_3,t_4	t_5
Permeability	P_2,P_3	P_2,P_3	P_2,P_3,P_4	P_2,P_3,P_4	P_1	(*)	(*)	P_5
Drainage	d_1	d_2	d_3	d_4	d_5	(**)	(**)	d_0
Gravel/ Rock	b_0	b_0	b_1	b_2	b_3	(*)	(*)	b_4
Flood threat	O_0	O_1	O_2	O_3	O_4	(**)	(**)	(*)
Salt/ Salinity (***)	g_0	g_1	g_2	g_3	(**)	g_3	(*)	(*)

Source: Arsyad (2005). Remarks: (*) = may have any characteristics, (**) = does not apply, (***) = commonly found in dry area

Classifications of land capability were arranged up to subclass category. The grouping into classes was based on the intensity of the inhibiting factors. The land was grouped into eight classes, namely class I to VIII. The threat of damage or resistance increases sequentially from class I to VIII. The land in class I to IV with proper management can be used for agricultural land with low- to high-level cultivation. The lands in class V, VI, and VII are suitable for pasture, planting trees or natural vegetation. Class VIII is used as a conservation area such as forests (Hardjowigeno and Widiatmaka, 2007).

Results and Discussion

Land use change

Based on the visual interpretation results of Google Earth imaging in 2004 and 2016, as well as verification results in the field, eight areas were identified to have undergone land use changes (Figure 1).

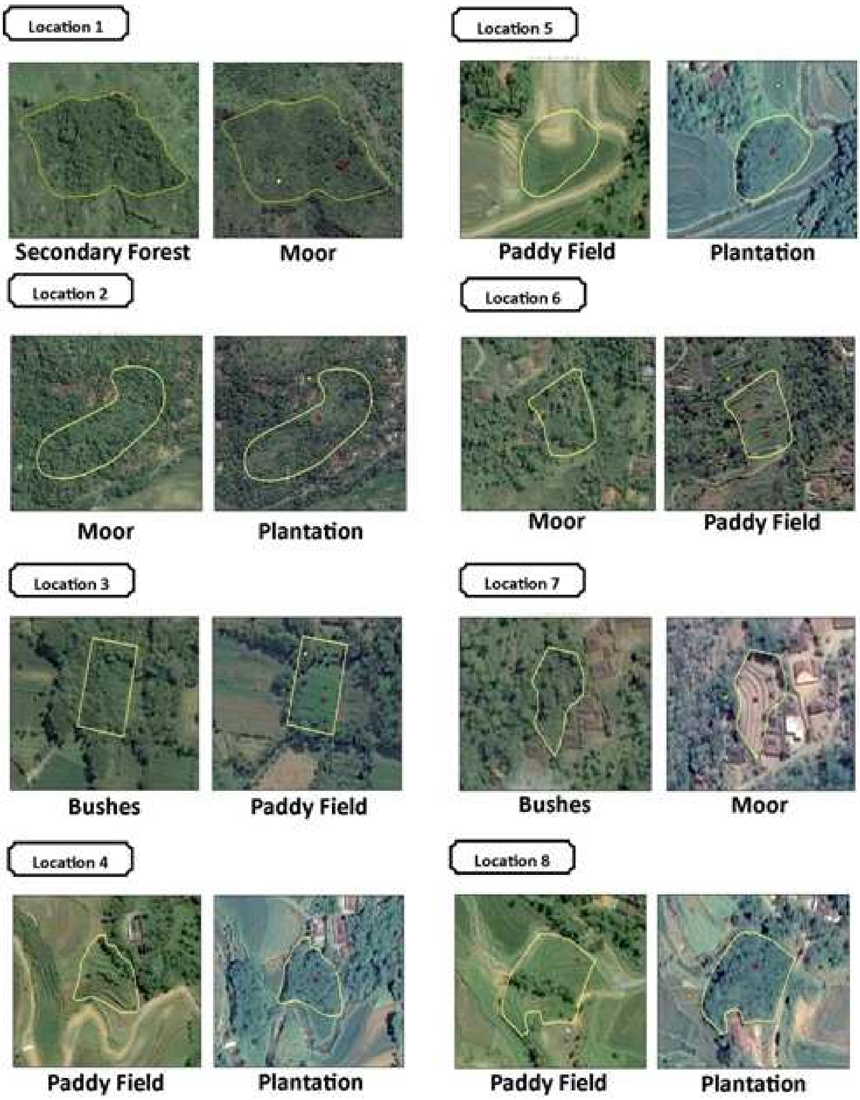

Figure 1. Locations of each land use change

Location 1 had changed from forest to moor, location 2 had changed from moor into plantation, location 3 had changed from bush to paddy field, location 4 had changed from paddy field to plantation, location 5 had changed from paddy field to plantation, location 6 had changed from moor into paddy field, location 7 had changed from bush to moor, and location 8 had changed from paddy field to plantation (Table 2). The soil types in Tirtomoyo District consist of Inceptisols, Entisols, Alfisols, and Ultisols.

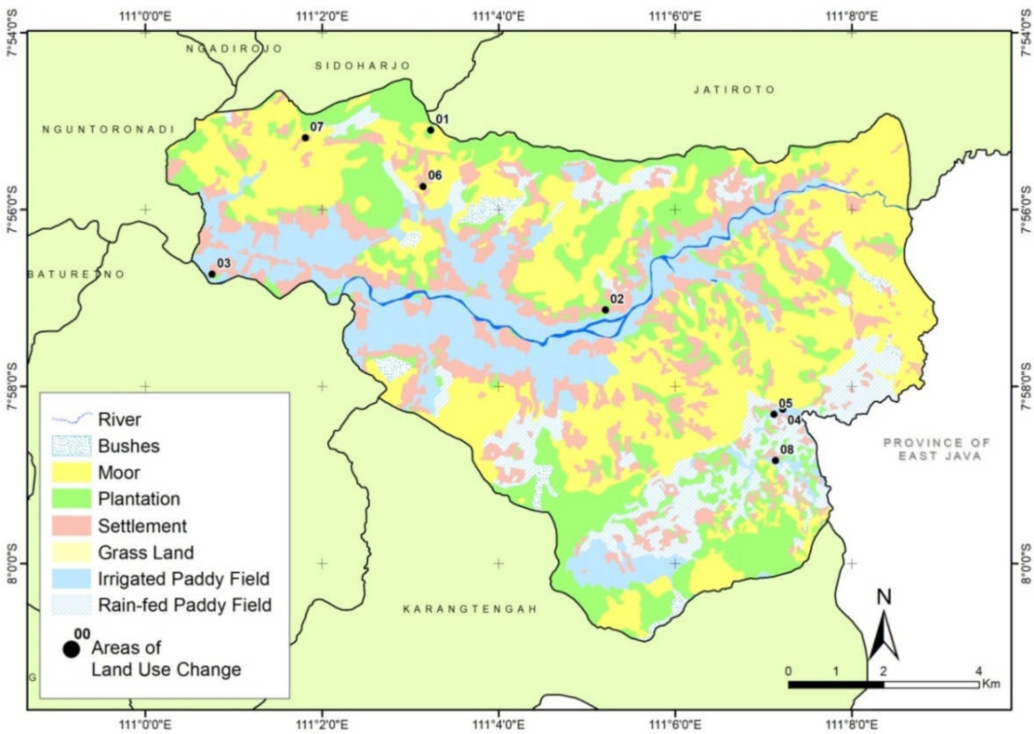

Figure 2. Land use change location map

Table 2. Land use changes in Tirtomoyo District

Location	Land Use		Coordinate	
	2004	2016	Latitude	Longitude
1	Secondary Forest	Moor	7°55'6.91"S	111° 3'15.03"E
2	Moor	Plantation	7°57'8.00"S	111° 5'12.53"E
3	Bushes	Paddy Field	7°56'43.94"S	111° 0'45.34"E
4	Paddy Field	Plantation	7°58'15.44"S	111° 7'13.02"E
5	Paddy Field	Plantation	7°58'18.93"S	111° 7'7.11"E
6	Moor	Paddy Field	7°55'44.46"S	111° 3'9.15"E
7	Bushes	Moor	7°55'11.42"S	111° 1'48.63"E
8	Paddy Field	Plantation	7°58'50.35"S	111° 7'8.10"E

Source: Spatial data analysis

Land characteristics in each location of land use change

The land characteristics in each land use change location consist of slopes, erosion sensitivity, erosion rate, soil depth, upper layer texture, bottom layer texture, permeability, drainage, gravel/rock, flood, and salinity. Based on field and laboratory analysis, the characteristics of each land use change location based on 2004 and 2016 data in Tirtomoyo District are presented in Table 3.

Changes of land capability class

Based on the land characteristics in each location of land use change presented in Table 3, a matching process between land characteristics and the modified USDA classification criteria of land use class (Arsyad 2005) was conducted. The changes of land capability class in each location of land use change are presented in Table 4. The land use change from secondary forest to moorland in site 1 indicated that land use change in the location had no effect on the change of land capability class, in which location 1 had a land capability class of VI with slopes as the primary inhibiting factor is 38% (slightly steep). The change of land use into the moor in 2016 had already demonstrated precise conservation measures in the form of terrace making, but in the moorland area, the presence of trench erosion was found.

Table 3. Land characteristics in each location of land use change

Location	Land Use	Slope	Erosion Sensitivity	Erosion Level	Soil Depth	Upper Layer Texture	Lower Layer Texture	permeability	Drainage	Gravel/ Rock	Flood	Salinity
1	Forest	Slightly Steep	low	Low	Deep	Medium	Medium	Medium	Rather good	Medium	No	Very Low
	Moor	Slightly Steep	Medium	High	Deep	Slightly fine	Slightly fine	Medium	Rather good	Medium	No	Very Low
2	Moor	Slightly sloping	Low	Low	Deep	Slightly fine	Slightly fine	Medium	Rather good	Medium	No	Very Low
	Plantation	Slightly sloping	Low	Low	Deep	Slightly fine	Slightly fine	Medium	Rather good	Medium	No	Very Low
3	Bush	Flat	Medium	No	Deep	Slightly fine	Slightly fine	Medium	Rather good	No	Yes	Very Low
	Paddy Field	Flat	Medium	No	Deep	Medium	Medium	Rapid	Rather good	No	Yes	Very Low
4	Paddy Field	Sloping	Medium	Medium	Deep	Slightly fine	Fine	Slow	Rather bad	No	No	Very Low
	Plantation	Sloping	Medium	Medium	Deep	Slightly fine	Slightly fine	Medium	Rather bad	No	No	Very Low
5	Paddy Field	Sloping	Medium	Low	Deep	Slightly fine	Fine	Slow	Rather bad	No	No	Very Low
	Plantation	Sloping	Medium	Medium	Deep	Fine	Fine	Slightly slow	Rather bad	No	No	Very Low
6	Moor	Slightly Steep	Medium	Medium	Shallow	Slightly fine	Slightly fine	Slightly slow	Rather bad	Medium	No	Very Low
	Paddy Field	Slightly Steep	Medium	Medium	Medium	Slightly fine	Slightly fine	Slightly slow	Rather bad	Medium	No	Very Low
7	Bush	Slightly Sloping	Medium	Medium	Deep	Slightly coarse	Slightly coarse	Medium	Rather good	No	No	Very Low
	Moor	Slightly Sloping	Medium	Medium	Deep	Slightly fine	Slightly fine	Medium	Rather good	No	No	Very Low
8	Paddy Field	Slightly Sloping	Medium	Medium	Deep	Slightly fine	Slightly fine	Slightly slow	Rather good	No	No	Very Low
	Plantation	Slightly Sloping	Medium	Medium	Deep	Fine	Fine	Slightly slow	Rather bad	No	No	Very Low

Source: Data analysis

Table 4. Land capability class changes

Location	Land Use	Land Capability	
		Class	Sub-Class
1	Forest	VI	VI-l_4
	Moor	VI	VI-l_4,e_4
2	Moor	III	III-l_2,b_1
	Plantation	III	III-l_2,b_1
3	Bushes	II	II-KE_3,d_2,O_1
	Paddy Field	III	III-P_4
4	Paddy Field	V	V-P_1
	Plantation	IV	IV-l_3
5	Paddy Field	V	V-P_1
	Plantation	IV	IV-l_3
6	Moor	VI	VI-l_4,k_3
	Paddy Field	VI	VI-l_4
7	Bushes	III	III-l_2
	Moor	III	III-l_2,e_2
8	Paddy Field	III	III-l_2
	Plantation	III	III-l_2

Source: Data analysis

This caused the land use change to moor in 2016 to have different inhibiting factors, but the soil remained in the same capability class (VI-l4, e4). According to Mujiyo et al. (2008), the existence of soil degradation in a production field can be caused by the lack of intensive care conducted by farmers. The maintenance of terraces or soil conservation on moors is generally not conducted intensively. Forests proved capable of reducing surface runoff and erosion, which can be explained because the forest has a thick layer of green litter, the covered soil surface by the plant canopy, and the presence of soil macro-fauna (Suprayogo et al., 2004).

The land use change from moor into plantations in location 2 did not affect the change of land capability class. The main inhibiting factors in the land capability class in location 2 are its slopes of 12% (slightly sloping) and gravel/rocks. The land use change into a plantation in 2016 into did not indicate any difference in land-use class at location 2 (III-l2, b1). Pratiwi (2014) revealed that soil physics characteristics in mixed plantation and moorland, in general, did not indicate any significant difference to total porosity, permeability, available water, and water retention capability when compared to the secondary forest. The land use change in location 3 from bushes in 2004 into paddy fields in 2016 indicated that the change had an impact on the change of land capability class. The use of land as moor in 2004 held the capability class of II with limiting factors of KE3, d2, O1 and it experienced decreased land capability class in 2016 with the land use as paddy field that is class III with limiting factor of P4. The inhibiting factor in location 3 is moderate to moderately rapid soil permeability, in which this condition is less ideal for land use as paddy fields due to poor water retention capability. This can be due to soil physical characteristics, especially the soil texture and structure in location 3 which are not suitable to be used as paddy field and that the paddy field at location 3 can be considered as new paddy field.

According to Agus (2007), new paddy field openings can be defined from two aspects, namely the paddy fields cultivation of fewer than ten years of age, and the physical properties of new paddy fields which are characterized by the lack of plough tread layer, so that its water use is relatively wasteful. Land use in 2016 at location 3 was paddy field with one year planting period consisting of paddy-paddy-CGPRT. Prasetyo (2007) revealed that the plough tread layer had not been formed because of the change into dry land planted with CGPRT, so that the soil characteristics return into the typical land condition in the dry land. The land use change from paddy fields into plantations indicated a change in the level of soil permeability. The permeability of paddy fields tends to be slower than that of the plantation. Monde (2008) stated that the increase in soil density due to soil management causes soil porosity to decrease; thus the capacity of the soil to let water pass into the ground (permeability) decreases. The too slow permeability in paddy fields is actually not good for paddy plants, although paddy plants grow well in flooded conditions, drainage at some level is still indispensable (Dariah and Agus, 2007).

The permeability of plantation is better than that of paddy field, although it is not very significant, this is assumed because the soil density of plantation land is lower than that of paddy field. Based on the research results of Syahed et al. (2015), the conversion of paddy field into plantation land for a more extended period and the above-planted commodities may cause changes in soil permeability. The characteristic change in location 5 showed the same unique physical property change to the class of land capability with that of location 4 namely the slow permeability on land use as paddy field. The level of permeability in the shift of paddy field use into plantation use increased, although the permeability on the plantation is included in the rather slow category. This is assumed to be caused by the density of the soil in the plantation area which is lower than that of paddy field in which the compaction was formed due to the management factor. The land use change from moorland into paddy field in location 6 did not affect the change of land capability class, but the land use change had an impact on the inhibiting factor. The most significant inhibiting factor in location 6 was the steep slopes of 32% (slightly steep) and the relatively shallow soil depth. The 2004 moorland use had 20 cm soil depth, and on paddy field use the depth was 30 cm. This is in line with the research conducted by Tufaila and Alam (2014) indicating that areas with steep slopes generally have thin soil solum. Different depths of the solum may be affected by several factors such as high erosion hazard or slow weathering process of the parent material. This can be seen from the type of soil which is generally a developing soil.

The management factor causes the increasing soil depth on paddy field use by farmers namely the making of land deepening terrace for the cultivation of paddy plants. The land use change from bushland to moorland in location 7 did not impact the land class capability, but there were differences in the limiting factors of the land capability class. The class of land capability in the bushland in 2004 was class III with inhibiting factor of slope (III-l2) whereas land use change in 2016 into moorland has a capability class of III with inhibiting factor of slope and erosion level (III-l2, e2). The reasons why vegetation cover impacts soil erosion can be explained in various ways. For example, green litter production and accumulation of organic matter can reduce groundwater loss (Wei et al., 2007). The level of erosion on land use is mild, but there is a need for appropriate conservation measures to prevent increased erosion. The vegetative method is one of the methods used to minimize the rate of erosion by utilizing plants to reduce the rate of soil erosion such as mulch cultivation and grass planting respective to land contour (Saputro, 2009).

Conclusion

The changes in land use lead to different impacts on the changes of physical properties in soil based on soil characteristics in each type of land use. Soil permeability and drainage in paddy fields are generally more hampered than in moorlands. Land use change of secondary forests into moor indicates an increase in soil erosion. The land use change from moorland into plantation land generally does not lead to changes in soil characteristics and are generally relatively similar. Land use changes have different impacts on land capability class. Locations 2 and 8 did not experience changes in land capability class or sub-classes. Locations 1, 6, and 7 did not change the land capability class, but there were changes in the sub-classes of land capability. Locations 3, 4, and 5 indicated changes in land capability class with a limiting factor of soil permeability level.

References

Agus, F. 2007. Introduction In : *New Wetland Rice Fields*. Indonesian Center for Agricultural Land Resources Research and Development. Bogor, Indonesia. 182p.

Arsyad, S 2005. *Soil and Water Conservation,* 2nd Edition. Pustaka IPB Press. Bogor, Indonesia.

Basuki, T.B., Purwanto, J., Fajarningsih, R.U. and Ani, S.W. 2010. The rate of the agriculture land conversion and the impacts of the agriculture land conversion to rice availability in Klaten Regency, Central Java Province. *Caraka Tani: Journal of Sustainable Agriculture* 25:38-42 (*in Indonesian*).

Central Bureau of Statistics of Wonogiri Regency. 2014. *Tirtomoyo District in Figures 2014*. BPS Kabupaten Wonogiri. Wonogiri, Indonesia (*in Indonesian*).

Central Bureau of Statistics of Wonogiri Regency. 2015. *Tirtomoyo District in Figures 2015*. BPS Kabupaten Wonogiri. Wonogiri, Indonesia (*in Indonesian*).

Dariah, A. dan Agus, F. 2007. Management of Physical Properties of New Open Rice Fields. In : *New Wetland Rice Fields.* Indonesian Center for Agricultural Land Resources Research and Development. Bogor, Indonesia. 182p.

Environment Southland. 2014. Land Use Change-Environmental Impacts. *www .es.govt.nz*. Accessed on 19th September 2017.

Fitriyana, G. 2016. *Affected Factors of Farmers' Decisions in Overturning Rice Field Function Becomes Palm Oil Plantation in Tanjung Lago Sub District Banyuasin Regency*. Abstract. Agribusiness Departement, Faculty of Agriculture Universitas Tunas Pembangunan (*in Indonesian*).

Hardjowigeno, S. and Widiatmaka. 2007. *Land Suitability Evaluation and Land Use Planning*. Gadjah Mada University Press. Yogyakarta. Indonesia (*in Indonesian*).

Junedi, H. 2010. Soil physic alteration of ultisols due to forest conversion into agricultural land. *Jurnal Hidrolitan* 1:10-14 (*in Indonesian*).

Mondal, M. and Mondal, Md.A. 2015. Land capability classification of Purba Medinipur District, W.B.: a geographical case study. *International Research Journal of Earth Sciences* 3(9): 13 20.

Monde, A. 2008. The Dynamics of Soil Quality, Erosion and Farmers Income due to Forest Conversion to Agricultural land and Cocoa Agroforestry in DAS Nopu, Central Sulawesi. Dissertation. Postgraduate of Institut Pertanian Bogor. Bogor. Indonesia (*in Indonesian*).

Mujiyo, Sumani, and Noorhadi. 2008. Land conversion mapping using GIS and remote sensing. *Caraka Tani: Journal of Sustainable Agriculture* 23:13-17 (*in Indonesian*).

Prasetyo, B.H. 2007. Genesis of New Wetland Rice Fields. In : *New Wetland Rice Fields.* Indonesian Center for Agricultural Land Resources Research and Development. Bogor, Indonesia. 182p.

Pratiwi, E.F. 2014. Darmaga Latosol and Jasinga Podsolic Physical Character in Some Land Use. Land Resources Department of Institut Pertanian Bogor. Indonesia.

Saputro, E.S. 2009. Erosion Hazard Level Analysis In Dry Tillage Area in Tretep Sub-district, Temanggung Regency. Geography Department of Universitas Negeri Semarang. Semarang. Indonesia.

Suprayogo, D., Widianto, Purnomosidi, P., Widodo, R. H., Rusiana, F., Aini, Z., Khasanah, N. and Kusuma Z. 2004. Degradation of soil physical properties as a result of forest conversion into coffee monoculture system: a study of soil macroporosity change. *Agrivita* 26: 47-52.

Syahed, A., Lubis, K.S. and Razali. 2015. Rice field characteristic due to land conversion into plantation in Tangga Batu Village, Hatonduhunan Sub-district, Simalungun Regency. *Jurnal Online Agroekoteknologi* 3: 1259-1265 (*in Indonesian*).

Thoha, A.S. 2008. Satellite Imagery Characteristics. Forestry Department of Universitas Sumatera Utara. Medan. Indonesia.

Tufaila, M. and Alam, S. 2014. Soil characteristics and land evaluation for rice field cultivation in Oheo Sub-District Konawe Utara District. *Agriplus* 24: 184-194 (*in Indonesian*).

Wei, W., Chen, L., Fu, B., Huang. Z., Wu, D. and Gui, L. 2007. The effect of land uses and rainfall regimes on runoff and soil erosion in semi-arid loess hilly area, China. *Journal of Hydrology* 335: 247–258.