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Mapping of Agricultural Land Use Change and Effect on Land Capability as a Basis for Land Use Direction in Nguntoronadi-Indonesia

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ABSTRACT

The occurrence of conversion of agricultural land can cause erosion proneness, low fertility soils, and decreased land productivity. Land conversion requires an evaluation of land capability, as a basis for direction to maintain land productivity. This study aims to determine the rate of conversion of agricultural land, land capability class, the determinants of land capability, and direction of land management on initial land and converted land in agricultural land, Nguntoronadi District, Karanganyar Regency. The method used is a survey, with the research area divided into 6 LMU (Land Map Units) represented by 6 sample points in each LMU including 3 points on fixed land and 3 points on converted land, resulting in 36 samples determined by purposive sampling. The research stages include; 1) Pre survey, 2) Survey, 3) Post survey. The results of the study show that the land-use change from 2011 to 2020 covers an area of 258.56 ha and a rate of 28.73 ha per year. The land capability of the research area on fixed land and converted land is classified into land capability III and class IV. Factors that determine land capability include soil erodibility and drainage. The recommended direction for land use and management for Nguntoronadi District is the provision of green manure, making terracing, and making drainage irrigation.

Keywords:
Drainage, land use, soil erodibility, terraces

1. Introduction

Indonesia is known as an agricultural country. Most of Indonesia's population has a livelihood in agriculture, but along with the increase in population and land requirements, there is a lot of conversion of agricultural land. Agricultural land that is most vulnerable to land conversion is paddy fields (Dewi and Rudiarto, 2013). Many paddy fields have been converted into other agricultural lands such as fields and plantations (Saputra and Budhi, 2015). Land conversion has a large relationship with soil characteristics (Don et al., 2011). A land conversion that is not following land capabilities can result in poor land productivity and land critical (Bhermana and Susilawati, 2019).

Some areas in Wonogiri Regency have natural resource potential that can be developed, one of which is Nguntoronadi District, whose territory is dominated by the agricultural sector, especially paddy fields. According to Purnaningsih and Purnamadewi (2019), based on Wonogiri Regent's Regulation Number 23 in 2015, the economic structure of Wonogiri Regency relies heavily on agriculture, the high and low of the economy is still strongly influenced by the added value generated by the agricultural sector. On the other hand, during the last 10 years, there has been quite a lot of land conversion in Nguntoronadi District. Nguntoronadi has low rainfall levels which have resulted in farmers choosing to convert paddy fields to dry fields where dry fields need less water than paddy fields (BPS Kabupaten Wonogiri, 2021). Activity of changing the function of agricultural land will cause problems, namely the limited land for the development of agricultural land to achieve sustainable food availability. For example, the area of paddy fields that continues to decrease will certainly have an impact on rice production, where the need for rice increases as the population increases from year to year, while the land area decreases (Mujiyo et al., 2018). Therefore, efforts are needed to maintain a balance, especially land use so that it remains by the capabilities of the land in Nguntoronadi District.

Agricultural land conversion activities require an evaluation of land capability, as a basis for land use according to directions to maintain land productivity (Ayalew and Yilak, 2014), and the sustainability of agricultural production without decreasing land quality in the long term (Atalay, 2016). Land capability can classify all types of land into VIII class depending on the level of risk of land degradation or a larger limiting factor gradually from class I to class VIII (Maryati, 2013). According to De Feudis et al., (2021) land capability can allow assessment based on the physical properties of the soil and climate. The land capability classification system consists of class VIII. Land classified as class I-IV is under designated agricultural cultivation, while class V-VIII capability is not suitable for agricultural cultivation and is more suitable for forests and nature reserves. According to Abdelrahman et al., (2016), the land conversion function can change its land capability due to different land management methods. Land conversion without paying attention to the land's ability can result in damage to land quality in terms of physics, chemistry, and soil biology, thereby affecting the decline in land productivity.

Based on the description of the problems that have been described, it can be estimated in general terms the causes and effects of the conversion of agricultural land. There is no information related to land conversion in Nguntoronadi District and how the land is capable of being used as agricultural land. The purpose of this study was to determine the rate of conversion of agricultural land from 2011 to 2020, identify the effect of land conversion and land use on land capability, find determinants of land capability, and provide recommendations for appropriate land management and direction based on class and determinants of land capability after the occurrence of land conversion in Nguntoronadi district, Wonogiri Regency, Central Java.

2. Materials and Methods

2.1 *Study Area Description*

The research was conducted in Nguntoronadi district, Wonogiri Regency, Central Java Province, Indonesia. The geographical location of Nguntoronadi District is at the coordinates of 7°54'06.79'' latitude and 110°57'30.56'' east longitude. Nguntoronadi District has mountainous contour conditions in the study area with smooth to rough reliefs. The tropical climate in this highland area makes the weather conditions rather dry with low rainfall. The type of soil in Nguntoronadi is Inceptisols. Most of the population of Nguntoronadi are farmers, so the percentage of agricultural land use is quite large (79.61%) with land use in the form of paddy fields, plantations, and dry fields. Upland land produces a lot of secondary crops, and vegetables with production reaching thousands of quintals, including 1,015 quintals of cucumber production, 78 quintals of cayenne pepper, and 48,600 kg of turmeric in each harvest period. (BPS Kabupaten Wonogiri, 2021).

2.2 Method

This study uses a survey method with an exploratory descriptive approach. The steps taken are; 1) Pre Survey, 2) Survey, 3) Post Survey. The first stage is pre-survey, the researcher prepares the permit and determines the observation point by making a Land Map Unit (LMU) of the area of land undergoing conversion in 2011-2020, then determining the distribution of sample points on the LMU map intentionally (*purposive random sampling method)*). Making LMU maps and determining sample points was done after knowing the area of land that was converted in the Nguntoronadi District. The analysis of land-use change in Nguntoronadi District can be carried out using the *Google Earth software* which is set by the year according to the research, namely from 2011-to 2020. The image obtained from *Google Earth* is then processed into the *software* to be overlaid with the LMU compiling map and continued to determine the LMU area and sample points. The LMU used is a land conversion area that produces 6 LMU. The research location in the Nguntoronadi Subdistrict is divided into 6 Land Map Units (LMU) in the area of land undergoing conversion, and each LMU consists of 6 sample points. Then, the 6 sample points were further divided into 2 areas, namely 3 fixed land points and 3 changing land points so that from 6 LMU a total of 36 sample points were obtained on fixed land and changed land.

The second stage is the survey, the survey is carried out by finding the location of the observation point, then observing the characteristics of the soil and land in the field and taking soil samples. In the process of observing various soil and land characteristics, among others, namely; 1) Surface slope that can be done using a clinometer, 2) Erosion level by observing the amount of erosion seen in the field, 3) Soil depth can be observed using a soil drill so that it cannot be penetrated by a drill, 4) Drainage can be observed by observing the presence or absence of yellow, gray spots on the ground, 5) Gravel/rock can be observed by observing rough materials, both surface rocks and outcrops, and 6) The threat of flooding can be observed whether or not there has been flooding around the research area, or you can ask the residents (Arsyad, 2010).

The third stage is post-survey, which is analyzing soil samples from various soil and land characteristics, including; 1) Erosion sensitivity using the calculation method, 2) Soil texture using the pipette method, 3) Permeability using the Falling Head Permeameter method, and 4) Organic matter using the Walkley and Black method which was carried out at the Physics and Soil Conservation Laboratory and the Chemistry and Soil Fertility Laboratory. Processing data from observations to determine the rate of land-use change, land capability class, and determinants of land capability as a basis for direction for land management.

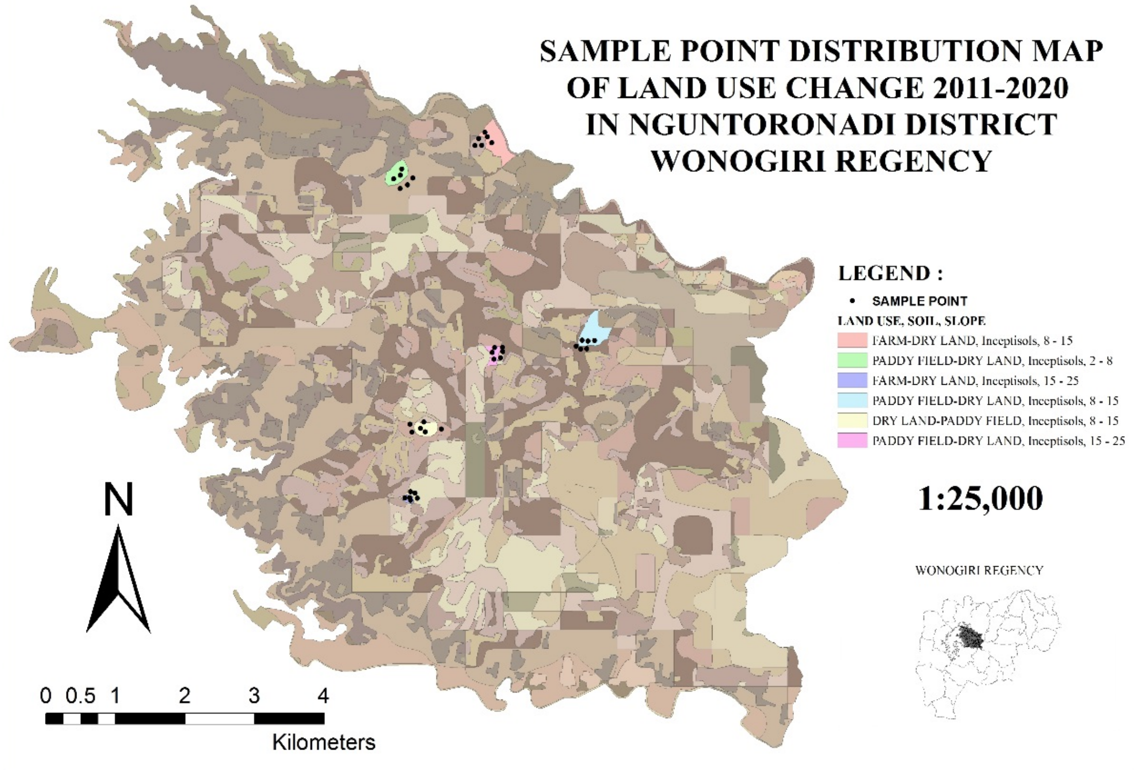

Figure 1. LMU Map and Land Use Change Sample Point 2011-2020.

2.3 Data Analysis

A. The rate of land-use change in the last 9 years (2011-2020). The rate of land conversion is determined by calculating the rate of land depreciation, the area of land in 2020 (L_t) is reduced by the area of land in 2011 (L_{t0}). Furthermore, it is divided by the timeframe of 2011 (T_0) to 2020 (T). with this equation can produce the average rate of land conversion per year.

$$V = \frac{L_t - L_0}{T - T_0}$$

Remarks:
V = Rate of conversion of agricultural land (ha/yr)
L_t = Agricultural land area in 2020 (ha)
L_{t0} = Agricultural land area in 2011 (ha)
T = Year 2020
T_0 = Year 2011

B. Determination of the land capability class is carried out by *matching* the observational parameters data with the Land Capability Classification Criteria Table (USDA Classification System) by determining the limiting factors and land capability units which are then grouped into I class to VIII class, where the higher the class, the worse the land capability means the level of degradation and the magnitude of the inhibiting factor will increase and the land use options that can be applied will be increasingly limited.

Table 1. Land Capability Classification Criteria (USDA Classification System)

Inhibiting/Limiting Factors	Land Capability Class							
	I	II	III	IV	V	VI	VII	VIII
Slope	$A(l_0)$	$B(l_1)$	$C(l_2)$	$D(l_3)$	$A(l_0)$	$E(l_4)$	$F(l_5)$	$G(l_6)$
Soil Erodibility	SE_1,SE_2	SE_3	SE_4,SE_5	SE_6	(*)	(*)	(*)	(*)
Erosion Rate	er_0	er_1	er_2	er_3	(**)	er_4	er_5	(*)
Soil Depth	sd_0	sd_1	sd_2	sd_3	(*)	(*)	(*)	(*)
Top 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
Undercoat Texture	sda	sda	sda	sda	(*)	sda	sda	sda
Permeability	P_2,P_3	P_2,P_3	P_2,P_3	P_2,P_3	P_1	(*)	(*)	P_5
Drainage	d_1	d_2	d_3	d_4	d_5	(**)	(**)	d_0
Gravel/Rock	rk_0	rk_0	rk_1	rk_2	rk_3	(*)	(*)	rk_4
Flood Threat	O_0	O_1	O_2	O_3	O_4	(**)	(**)	(*)

Source: Arsyad, (2010)

Description:

(*) = can have any properties

(**) = not applicable

(***) = generally found in dry climates

C. The effect of conversion, land use, and determinant factors of land capability was analyzed by statistical tests of T-test, Analysis of Variance, and Pearson's correlation test. The ANOVA test is used to determine whether or not there is a significant effect between land characteristics on land capability, the T-test is used to determine whether or not there is a real difference in land-use change on land capability, then the correlation test is used to determine which of the various parameters most determine land capability its value is related to land capability. All statistical analyses were performed with IBM SPSS Statistics 25 software.

3. Results and Discussion

3.1 Land Use Change

The conversion of agricultural land in the District of Nguntoronadi is very diverse but is dominated by the conversion of paddy fields to dry fields. The occurrence of land conversion in 2011-2020 with a total area of land conversion of 258.56 ha and a percentage of 3.88% of the total area of Nguntoronadi District. The conversion of agricultural land can be seen in Table 2 which presents data on the type, rate, and extent of conversion that occurred in the research area.

Table 2. Agricultural Land Use Change in Nguntoronadi District 2011-2020

Num	Types of Land Use Change	Wide (ha)	Rate (ha/yr)	Percentage (%)
1	Plantation-Dry Field	37.6	4.18	14.54
2	Paddy Field-Dry Field	183.62	20.4	71.02
3	Dry Field-Paddy Field	7.56	0.84	2.92
4	Plantation-Paddy Field	6.87	0.76	2.66
5	Dry Field-Plantation	16.2	1.8	6.27
6	Paddy Field-Plantation	6.71	0.75	2.6
	Total Area	**258.56**	**28.73**	**100**

The results showed that the area and rate of land conversion in Nguntoronadi District in 2011-2020 were the highest for paddy fields with an area of 183.62 ha, the land conversion rate of 20.40 ha/year, and a percentage of 71.02%. In addition, the area and the lowest rate of land-use change are paddy fields into plantations with a total area of 6.71 ha, a rate of land conversion of 0.75 ha/year, and a percentage of 2.60%. The land changes that experienced the most changes were paddy fields to dry fields. This is in line with Sumaryanto and Tahlim (2015) who states that paddy fields are agricultural land that is most prone to land changes. Paddy fields in general have a high vulnerability to conversion due to unfavorable environmental conditions and have an impact on decreasing rice production after land conversion (Uchyani and Ani, 2012).

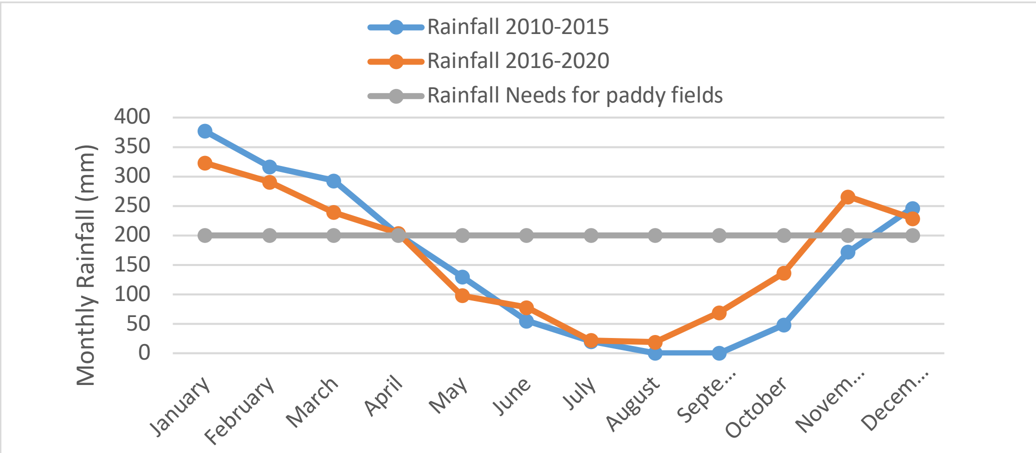

Figure 2. Rainfall Curve in Nguntoronadi District of 2010-2020

The conversion of paddy fields to dry fields is caused by the lack of water availability during cultivation for a long time so farmers prefer to convert paddy fields to dry fields. Rice fields planted with lowland rice require the availability of sufficient water to support the growth and yield of good rice plants (Rusmawan et al., 2015). So the availability of little water makes farmers change the use of their paddy fields. Figure 2 shows the trend of rain in Nguntoronadi District, which shows low rainfall and the potential for drought if the land is designated as rice fields. Monthly rainfall in the last 10 years shows less intensity from January to December. The water requirement for rice plants is in the range of an average of 200 mm, while the rainfall that can meet the availability of water is only for 5 months, namely January, February, March, April, and December. And in other months the rainfall is very low, below the average water requirement for rice plants. Therefore, farmers choose to convert paddy fields into dry fields so that it does not require a lot of water availability. This is in line with Paski et al., (2018) that the requirements for good rice plant growth are in areas that have hot air and contain lots of water, have ideal rainfall of about 200 mm per month, and ideal rainfall per year is around 1,500-2,000 mm with normal temperature is around 19-27 ^{0}C, but the most optimal temperature is around 23 ^{0}C.

The land in several locations is close to water sources and allows the connection of land irrigation so that it is appropriate for the conversion of dry fields to paddy fields, with a total area of 7.56 hectares. In addition, the location is on a gentle slope, and there is little surface rock. Irrigation water sources are very important for the growth of lowland rice plants, and the supply of irrigation water will affect the level of rice production (Fadli and Murdiana, 2016). It has been suggested in government regulation in the Circular Letter of the State Minister of Agrarian Affairs/Head of BPN number 460-1594 dated June 5th 1996 (Isa, 2012) which discusses the prevention of conversion of paddy fields to dry fields addressed to the Governor/Mayor to provide education to the public. so as not to block irrigation canals, not to dry up paddy fields and convert them to dry fields, and not to convert paddy fields to land for building purposes.

Dry land turned into plantations is on a gentle slope of about 15-40%, this natural factor makes conversion and slope factors related to erosion vulnerability. This is in line with Rudoy et al., (2021) that annual plants can reduce erosion better than annuals, also annual plants have a positive effect on soil conditions such as preventing erosion, depletion of carbon accumulation, and methane CH_4 in the soil. The conversion of garden land into dry fields that occurs in the research area may aim to prevent the lack of income for farmers, in line with Devianti, (2016) that the lack of economic income cannot meet needs so the conversion of garden land into dry fields. Plantations dominated by annual crops require a long time to produce, while dry land dominated by seasonal crops can produce monthly yields. However, according to Purwaningsih et al., (2014), each district of the Wonogiri Regency including the Nguntoronadi District has various leading sectors. The dominant sector in Wonogiri is the agricultural economy, which means that the economy of each district is supported by the agricultural sector.

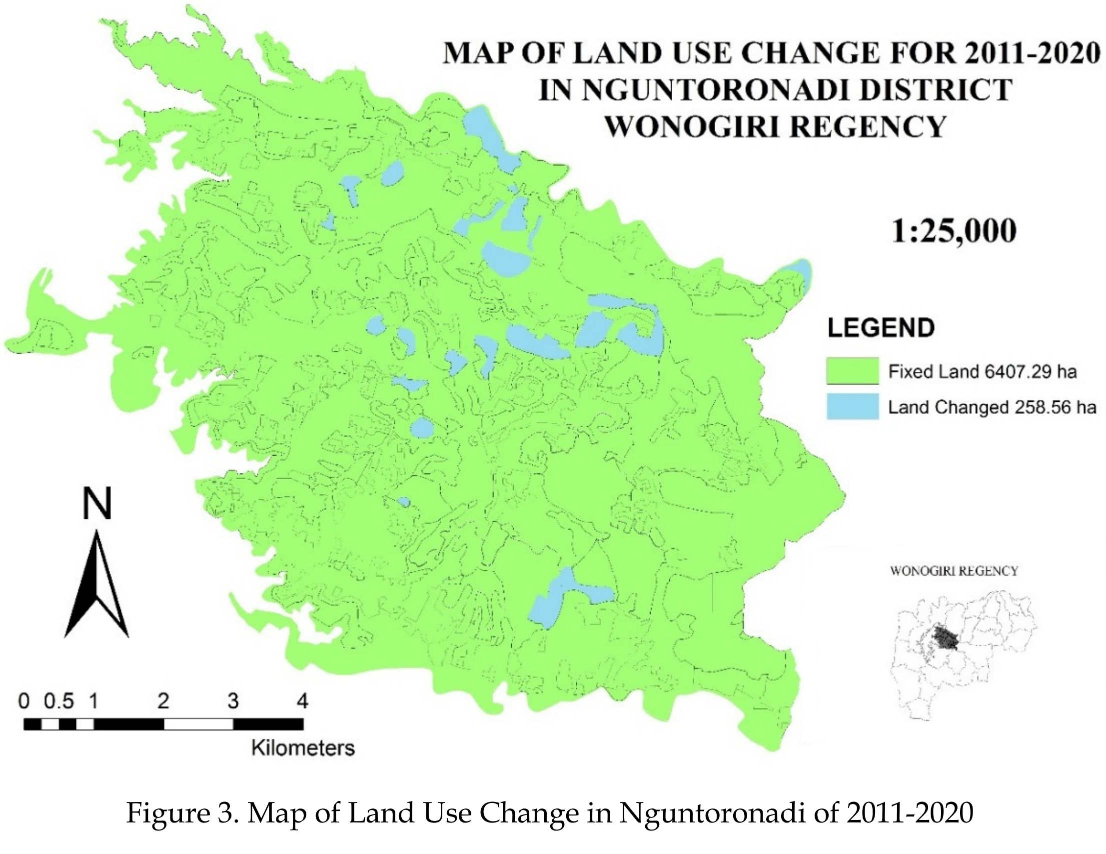

Figure 3. Map of Land Use Change in Nguntoronadi of 2011-2020

3.2 Land Capability

There are two classes of land capability after the land-use change occurs in Nguntoronadi District, namely class III and IV. The recapitulation of land capability is presented in Table 3.

Table 3. Recapitulation of Land Capability Classes for each LMU in Nguntoronadi District

LMU	Land Use	Land Capability Class	
		Fixed Land	Land Changed
1	Plantation-Dry Field	IV-SE6	IV-SE6,D4
2	Paddy Field- Dry Field	IV-D4	IV-RK2
3	Plantation - Dry Field	IV-SL3,D4	IV-SL3,D4
4	Paddy Field- Dry Field	III-SL2,D3	IV-D4
5	Dry Field -Paddy Field	IV-SE6,D4	III-SL2,SE5,D3,RK1
6	Paddy Field- Dry Field	IV-SL3,D4	IV-SL3,D4

LMU 1 fixed land and land conversion did not change the land ability, but on land that was converted from plantation to dry fields, the soil drainage conditions worsened. In LMU 2 there was a conversion of paddy fields into dry fields which did not affect the change in land capability. However, in LMU 2 the initial land and the converted land have different limiting characteristics, which in the initial land the drainage conditions are poor, while in the converted land the percentage of surface rock is too high to be a limitation of land capability. Surface rocks can slow the rate of water flow so that a lot of water stagnates on the soil surface, and has the effect of reducing the available water capacity in the soil (Priori et al., 2021), and plants will lack water for metabolic processes, this is in line with (Kapoor et al., 2020) that water drought greatly affects plant growth processes, which in turn will cause severe disturbances in overall plant metabolism.

In LMU 3 and LMU 6, the fixed land and the converted land did not have any change in land capability. The land has the same limiting characteristics, namely steep slopes and poor drainage. The slope of this slope cannot be changed because it is a permanent topography of the area. Steep slopes have less chance of puddles because they are in a sloping area (Rahardjo, 2020). After all, the infiltration rate of surface runoff from higher rainfall usually causes higher erosion rates. Land conversion in LMU 4 causes changes in land capability. The ability of the land in LMU 4 has decreased due to the conversion of paddy fields to dry fields and the limiting characteristic, namely the worsening drainage conditions. In LMU 5, there is an increase in ability which can be after the conversion of dry fields into paddy fields. In addition, the condition of erosion sensitivity and drainage is also getting better.

The conversion of agricultural land is not significantly different from the ability of the land. However, the difference in land use at each observation point affects the land capability (F-count = 3587, P-value = 0.039, N = 36). In line with the statement of Adnyana and As-syakur, (2012) that land capability will change along with changes in land use. The difference in land capability for each land use is presented in Table 4.

Table 4. Land Capability in Multiple Land Uses

Land Use	Land Capability Class
Paddy Field	3.58a
Plantation	3.83ab
Dry Field	4.00b

Remark: Numbers followed by the same letter show no significant difference in the DMRT test with a 5% confidence level

The difference in land capability in each land use shows that paddy fields are the land with the best capabilities in the Nguntoronadi research area. Land capability III in accordance with the direction of land use. Whereas inland capability IV, can be used as land use for seasonal crops and annual crops with certain land management. Land capability IV requires appropriate and more conservation measures than land capability III to maintain fertility levels and soil physical conditions which are very much needed by intensively cultivated agricultural lands such as annual crops and annual crops. (Budiarta, 2013) that land with ability class III-IV is more suitable for dry land use.

3.3 Determinant Factor of Land Capability

The determining factor in this study is the soil characteristics that most determine the land capability, which values are interrelated with the land capability. In Table 5, the results of statistical tests are presented using a correlation test between soil and land characteristics and land capability class.

Table 5. Land Capability Class Determinant Parameters

Parameters	LC	SL	SE	ER	SD	TLT	UT	P	D	GR/RK	FT
Land Capability											
Slope	.104										
Soil Erodibility	.346*	.370*									
Erosion Rate	.234	.328	.190								
Soil Depth	.286	.383*	.427**	-.094							
Top Layer Texture	.293	.290	.865**	.192	.293						
Undercoat Texture	.038	.047	.112	.126	.249	.196					
Permeability	-.198	-.109	-.033	-.012	-.195	.006	.011				
Drainage	.378*	.025	-.006	.124	.126	.000	.152	-.249			
Gravel/Rock	.325	-.134	.068	.107	.207	-.060	.008	-.045	.000		
Flood Threat	.043	-.113	.166	.141	-.043	.177	.266	-.395*	.000	.009	

Remark: N = 36, followed numbers (*) are correlated at the 5% level and (**) have correlated at the 1% level.

Soil characteristics that have a close and significant relationship with land capability are erosion and drainage sensitivity. The relationship between erosion sensitivity and drainage has a positive value, as the value of erosion and drainage sensitivity increases, it will worsen the land capability in the study area. Erosion sensitivity called soil erodibility is defined as whether or not the soil is sensitive to transport by raindrops (Manyiwa and Dikinya, 2013). In Table 5 it is explained that soil texture is highly positively correlated with soil erodibility. Soil texture in the Nguntoronadi District area in each LMU has a fine to coarse texture condition, in line with Ardianto and Amri (2017) that the coarser the texture, the higher the soil erodibility, but on the other hand, the finer texture, the lower the soil erodibility. Then in addition to texture, which has a highly positively correlated value is soil depth to soil erodibility, meaning that the shallower the depth of the soil, the worse the soil erodibility. inline with Layeghi et al., (2020) that the thinner the soil layer (shallow soil depth), the higher or worse the soil erodibility.

Drainage is a determining factor and a limiting characteristic found in almost all LMU areas. Drainage is the ability of the soil to drain and regulate excess water that is in or on the soil surface. Almost all research areas have poor drainage. Excessive water more often stagnant on the ground surface is caused by the influence of slopes, shallow groundwater, and rainfall (Hantarto, 2017).

3.4 Land Use and Land Management Directions

Different land use due to conversion causes soil characteristics to change and affects land capability. The land capability of the Nguntoronadi is classified III and IV, with the determinants of high erosion sensitivity and poor drainage. Land use directions and management efforts recommended in this study are based on observations of land capability class and land characteristics which are the determining factors for land capability, paddy fields in land capability class III, while land capability IV is for use of dry fields and plantation, with land management to overcome soil erodibility and drainage.

Erosion sensitivity management at LMU 1, 2, 3, 5, and 6 can be provided with cover crops (Sulistyaningrum et al., 2012). Cover crops are one solution that reduces erosion rates (Loannisa et al., 2020). In addition, other recommendations for improvement on the determinants of soil erodibility are the construction of mound terraces on LMU 1 and LMU 5 fixed lands which are on a slope of 8-15%. The mound terrace can be used on dry fields and plantations. The mound terrace is recommended because it can reduce soil erosion and can be used for dry fields and plantations (Dewi et al., 2012). While in LMU 5 land conversion, it is recommended to make bench terraces because bench terraces can be used for dry or wetland.

Management of soil drainage in the research area as the basis for land improvement is the construction of drainage irrigation. Improved drainage will affect the rate of water flow into the soil on-air aeration in the soil so that later the soil will be easier to cultivate and the roots of plants will develop properly which can absorb water and nutrients in the soil (Akbar et al., 2020). However, generally, paddy fields require poor drainage. Although paddy fields have the potential for rice growth in waterlogged land if the land has good irrigation and drainage facilities. According to Setiawan et al., (2015) that water management in paddy fields is very important to maintain excessive water levels.

4. Conclusion

The rate of conversion of agricultural land in Nguntoronadi District in 2011-2020 is 28.73 ha/year with the largest rate being in paddy fields to dry fields which has a rate of 20.40 ha/year. Land capability in Nguntoronadi is classified III and IV. Land capability is influenced by the type of land use, where paddy fields have the best land capability. Land characteristics that determine the ability of land before and after the occurrence of land-use change are soil erodibility and drainage. The recommended management efforts for conditions of high erosion sensitivity are applying crop rotation, covering crops, and making terraces. Meanwhile, drainage management is suggested by improving drainage irrigation.

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