250 IDENTIFICATION OF MERAPI’S SOUTHERN SIDE SLOPE LANDUSE TO SUPPORT ANALYSIS OF FLOOD FACTORS IN YOGYAKARTA URBAN AREA

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FOREWORD

The discussions of agrarian arrangement, land administration and spatial planning should be seen as an integrated entity and cannot be separated each other. On a more traditional way, land administration giving the function to provide land data for taxation purpose, but on a broader context, recent development refers to the establishment of land administration system scoping a more extensive function such as supporting economic development, environmental management, and social stability and justice. In this condition, the need of an integrated land administration system, covering aspects of agrarian arrangement and spatial planning, is inevitable. On a broader context, integrated land administration, agrarian and spatial planning covering some aspects correlated each other. The implementation of high technology in land measuring and mapping, supported with a solid and up to date land database management for cross-sectors purpose, data sharing policies, multi-sectors management related to land management, consistencies between agrarian arrangement, land administration and spatial planning to avoid conflicting on the implementation, and also how those can function optimally as a tool to achieve social justice and improvement of quality and stability of life. This is not an easy work, especially for developing countries such as Indonesia, where those needs are usually conflicting with the need of economic growth and infrastructure development as 'the one and only measurement tool" to quantify the success of development. Other issues, such as access and asset justice of land, poverty, gender and generation, customary land and indigenous people, community empowerment, and other technical issues such as disaster management and land use, utilization and tenure control are neglected on agrarian and spatial planning practices.

This proceeding is a collection of papers presented on the international seminar of "Integrated Land, Agrarian and Spatial Planning for Sustainable Development" held by STPN on September 19-20, 2019, contain ideas, findings and experiences, practical and empirical, related to agrarian arrangement, land administration and spatial planning, to provide recommendation for a more comprehensive of integrated agrarian, land and spatial planning implementation. The findings and discussions are expected to be a tool for multi-sectors stakeholders related to the issues, not only limited to the Ministry of Agrarian Affairs and Spatial Planning, but also for other institutions, as a part of counteraction of perceptions related to land management and spatial planning, for a better future and sustainable development of Indonesia.

CONTENTS

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Abstract

Water resources on earth have a fixed volume, but the distribution undergoes changes in the dimensions of time and space through the mechanism of the hydrological cycle. In recent times, the imbalance of the hydrological cycle has begun. In the dry season, the availability of water is increasingly limited, characterized by increasingly frequent and widespread drought phenomena. On the other hand, in the rainy season the phenomenon of flooding is increasing in a large area. Landuse is one of the factors that can have a broad influence on the occurrence of flooding. The phenomenon of flooding and puddle in the Yogyakarta Urban Area in recent years has tended to increase. When rainfall is high, puddles are found in various locations in Yogyakarta Urban Area. These puddles often occur on the main road, thus disrupting community mobility. Analysis related to flooding and puddle in the city of Yogyakarta which is on the south side of the slopes of Merapi is important due to the high economic and socio-cultural activities and also mobility of the population in this region. This study is intended to obtain one of the factors that can affect the incidence of flooding, namely landuse. The research applies qualitative descriptive analysis with watershed concept. The data are derived from remote sensing images in 2017. The results of the study are visualization of the spatial distribution of types of landuse and surface runoff coefficients based on spatial variations in the concept of watershed and spatial planning.

Keywords: Landuse, runoff coefficient, flood, urban area

A. Introduction

As one of the natural resources, water volume on earth is fixed, but its distribution undergoes changes in the dimensions of time and space through the hydrological cycle mechanism. From time to time, there are water resources that are stored as water vapor, rain water, sea water, groundwater, and water stored in vegetation. The balance of the hydrological cycle is influenced by many factors, such as meteorological and climatological elements and land cover. In recent times, the imbalance of the hydrological cycle began to be felt. One of them is the imbalance in water distribution between dry season and rainy season. In dry season, the availability of water is increasingly limited, characterized by the more frequent and widespread phenomenon of drought. On the other hand, in rainy season, the phenomenon of flood is increasing in large areas.

The occurrence of flood is strongly influenced by many factors. Kodoatie and Sjarief (2002 in Kodoatie 2013) state that flood and puddle that occurred at certain location were caused by changes in landuse in watersheds, garbage disposal, erosion and sedimentation, slums along rivers/drainage, improper flood control system planning, rainfall, river physiographic/geophysical effects, river capacity and inadequate drainage, tides effects, land subsidence and tides, land drainage, weirs and water structures, and damage to flood control buildings. Landuse is a factor that can have a large influence on flood in a broad scope. One example is the occurrence of flood in the middle or downstream areas of the river runoff can be caused by landuse errors in the upstream area.

In the watershed concept, Yogyakarta Urban Area is in the middle zone. An analysis related to flood and puddle in Yogyakarta City, located on the southern side of Merapi slope is important, given the high economic and socio-cultural activities and population mobility in the region. The occurrence of flood in Yogyakarta City can certainly disrupt the economic and socio-cultural activities. In Regional Regulation No. 2 of 2010 concerning the Spatial Planning for the Yogyakarta Province in 2009-2029, Yogyakarta City has a position as the National Activity Center (PKN). This PKN has a function to serve international, national or several provincial scale activities. Meanwhile, news of floods and puddle is getting more frequent in Yogyakarta Urban Area. When rainfall is high, puddles are found in various locations in Yogyakarta City. There were around 71 puddle prone points in nine areas in the city of Yogyakarta that need to be anticipated (Kompas.co, 2008). These puddles often occur on major road sections so that it disrupts community mobility. There were 35 puddle points on the streets of Yogyakarta City that could potentially disrupt traffic flow when heavy rains lasted for more than two hours (Tempo.co, 2015). Poor water absorption or drainage channels in a number of roads, massive landuse changes in a number of catchment sites, and narrowing of river bodies cause flood in Yogyakarta City, especially in river channels and roads in Yogyakarta City (Cendananews.com, 2017).

B. Material and Methods

This study was intended to identify landuse on the southern slopes of Merapi as a supporter of flood factor analysis in urban Yogyakarta. From these objectives, research objectives include: 1) Interpretation of types of landuse, and 2) assessment of runoff coefficients based on the type of existing landuse. Using the watershed concept approach, the scope of research is not limited to the Yogyakarta Urban Area, but also includes the upstream area on the southern slopes of Merapi. Administratively, the spatial scope of the research is presented in Table 1 and Figure 1.

Table 1. Spatial Scope of Research

City/Regency	District	Information
Yogyakarta City	Wirobrajan Umbulharjo Tegalrejo Pakualaman Ngampilan Mergangsan Mantrijeron Kraton Kotagede Jetis Gondomanan Gondokusuman Gedongtengen Danurejan	Yogyakarta Urban Area
Bantul	Banguntapan Sewon Kasihan	
Sleman	Depok Gamping Godean Kalasan Mlati Ngaglik Ngemplak	
	Turi Pakem Cangkringan Seyegan Sleman	The upstream area of Yogyakarta Urban Area (watershed system approach)

Source: Data Processing (2018)

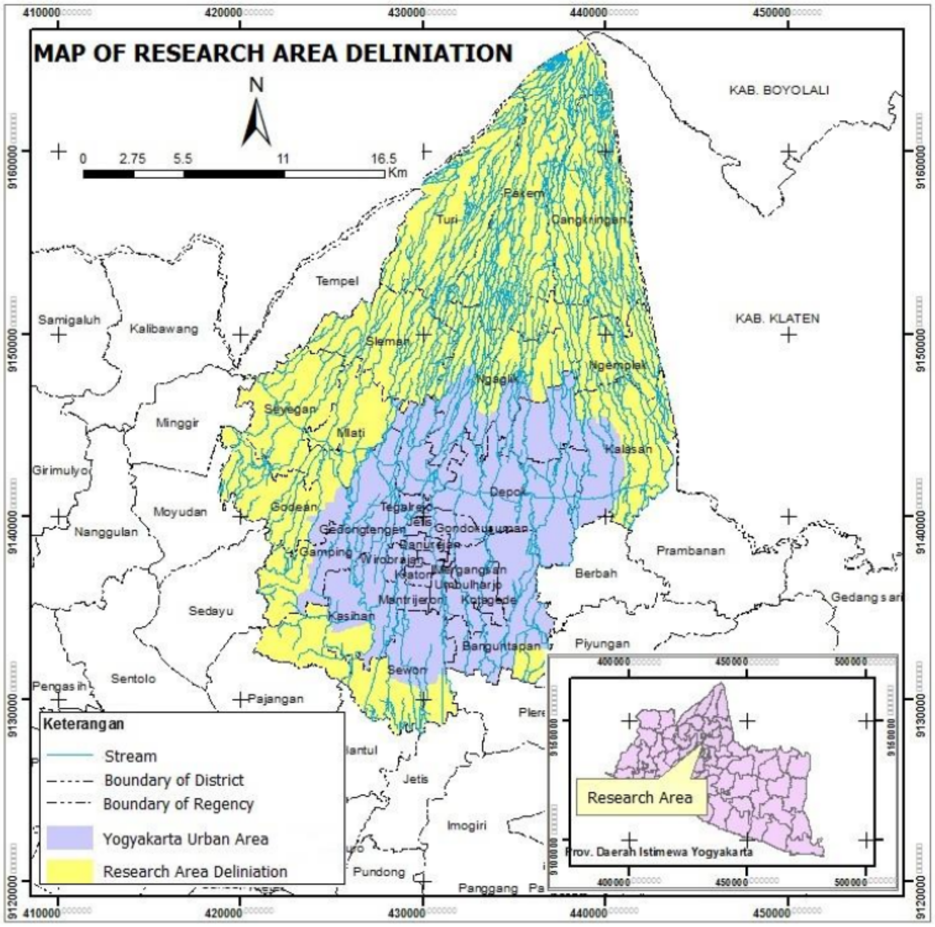

Figure 1. Delineation of Research Area

1. *Watershed Concept*

Watershed is a land area that is an integral part of a river and its tributaries, which functions to capture, store, and release precipitation to lakes or to the sea naturally, the boundary on land is a topographic and boundary on sea is where the water still affected by land activities (Law Number 7 of 2004). Kodoatie and Sjarief (2010) argued that the watershed is a area of the naturally formed water system where water is captured (derived from precipitation) and will release from the area towards related tributaries and rivers. Suprayogi, et al. (2013) suggested that the watershed zones can be done based on administration, management area, and runoff and sedimentation processes. As presented in Figure 2, based on runoff and sedimentation processes, watersheds can be divided into 3 zones, namely: 1) overland flow and sediment production zones, 2) surface runoff and sediment transfer zones, and 3) sedimentation zones.

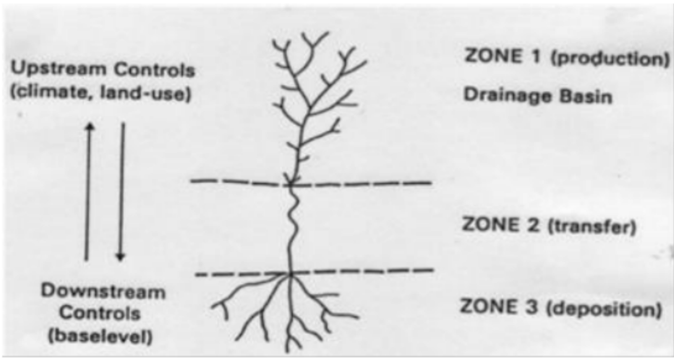

Figure 2. Illustration of Watershed Zone on the Basis of Runoff and Sedimentation Processes

Source : Newson (1997, in Suprayogi, et al., 2013)

2. *Flood Factors*

Flood can occur due to natural factors and human factors (Suprayogi, et al., 2013). According to Maryono (2014), several factors causing floods are extreme climate, decreasing watershed carrying capacity (including river development patterns), planning errors and implementation of regional development, errors in the concept of drainage, and socio-hydraulics (errors in people's behavior towards hydrological components- hydraulic).

Kodoatie (2013) states that flood that occurs at a location is caused by, among others, the following reasons: 1) Changes in landuse in watersheds, 2) Waste disposal, 3) Erosion and sedimentation, 4) Slums along rivers/drainage, 5) Inadequate flood control system planning, 6) Rainfall, 7) Effect of river physiography/geophysics, 8) River capacity and inadequate drainage, 9) Effect of tide, 10) Land subsidence and tidal, 11) Land drainage, 12) Weirs and water structures, and 13) The damage of flood control buildings.

3. *Landuse and Flood*

Landuse regulation is important because it is related to the ability of land to absorb rainwater/presipitation into the ground as a groundwater supply. The more water that enters the ground (infiltration), the chance of surface runoff (overland flow) to become a surface runoff (flood) is also smaller. Basically, the more permeable the land surface, the greater the chance of water to infiltrate so that the runoff coefficient gets smaller. Each type of landuse has a variable runoff coefficient. A description of the runoff that occurred can be presented in the hydrograph, as in Figure 3.

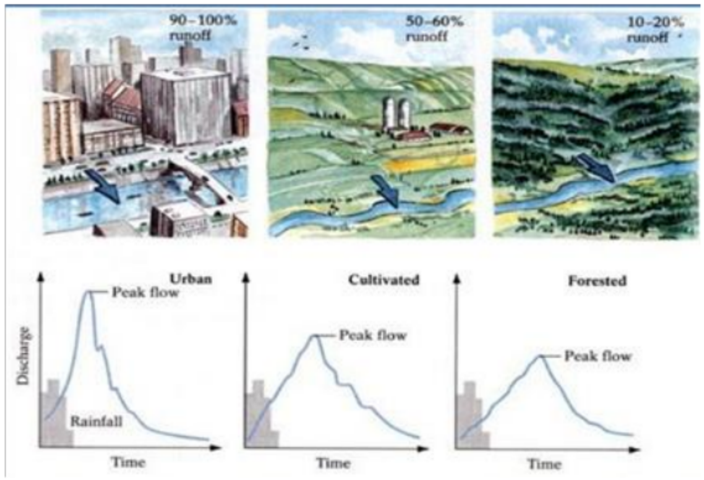

Figure 3. The Relationship Between Land Cover and Surface Runoff Magnitude

4. *Urban Area*

Urban areas are areas mainly for non-agricultural activities with the arrangement of the area functioning as a place for urban settlements, centralization and distribution of government services, social services, and economic activities (Law Number 26 Year 2007). To be categorized as urban, an area must have the following criteria (Sinulingga, 2005): 1) Population density above 500 people per Km^2, 2) Households involved in agricultural activities are less than 25%, and 3) Have more than 8 urban facilities such as electricity, clean water, secondary schools, theaters, markets, banks, post offices, and so on.

5. *Method*

The approach used in this study emphasizes on qualitative descriptive analysis. The results of research conducted with this approach are visualization of spatial distribution of land use types and surface runoff coefficients based on spatial variations in watershed and spatial concepts. The quantification carried out in this study is limited to a simple description of each type of the landuse area and the surface runoff coefficient value. The land use identification in this study uses the 2017 recording satellite imagery downloaded from the Google Earth application. The image is then interpreted manually using ArcGis mapping software. The land use classification used refers to the classification of runoff coefficient values according to Haryono (1999), Soewarno (2000), and Tay and Afshar (2014) as presented in Table 2.

Table 2. Runoff Coefficient Used in the Research

Haryono (1999)		**Soewarno (2000)**		**Tay and Ashar (2014)**		**Classification and Value used in the Research**	
Landuse	**Runoff Coefficient**	**Landuse**	**Runoff Coefficient**	**Landuse**	**Runoff Coefficient**	**Landuse**	**Runoff Coefficient**
Business and Shopping Center	0,90	Tropical Forest	<0,03	Downtown business	0,70-0,95	Forest	0,05
Industry	0,80	Production Forest	0,05	Heavy industrial	0,60-0,90	Farm/Field	0,20
Housings (20 houses/Ha)	0,48	Shrubs	0,07	Multiresidential units, attached	0,60-0,75	Ricefield	0,15
Housings (30 houses/Ha)	0,55	Ricefields	0,15	Light industrial	0,50-0,80	Settlement (20 houses/Ha)	0,48
Housings (40 rumah/Ha)	0,65	Farmland, Plantation	0,40	Neighbourhood businesses	0,50-0,70	Settlement (30 houses/Ha)	0,55
Housings (60 houses/Ha)	0,75	Settlement	0,70	Cultivated lands with loamy soils	0,40-0,45	Settlement (40 houses/Ha)	0,65
Ricefield	0,15	Paved Roads	0,95	Suburban residential	0,25-0,40	Settlement (60 houses/Ha)	0,75
Pool	0,20	Solid Building	0,70-0,90	Playgrounds	0,20-0,35	Industry	0,80
Mixed Garden	0,10	Scattered Building	0,30-0,70	General unimproved lands	0,10-0,40	Cemetery	0,25
		Rooftop	0,70-0,90	Park and cemeteries	0,10-0,25	Airport	0,30
		Dirt Roads	0,13-0,50	Woodlands with sandy soils	0,10-0,15	Open Land/Field	0,30
		Hard Layer of Gravel,	0,35-0,70			Undeveloped Land in Yogyakarta City (of parks, yards, fields, cemeteries)	0,25
		Hard Layer of Concrete	0,70-0,90				
		Park, yard	0,05-0,25				
		Field	0,10-0,30				
		Farm, Field	0,-0,20				

Source: Haryono (1999), Soewarno (2000), Tay and Ashar (2014)

Rating of run off coefficients are assessed in the district unit. Using runoff coefficient data for each type of landuse and area of each district, the calculation of runoff coefficient in the district unit is as follows:

$$c = \frac{\sum Ci\,Ai}{\sum A1}$$

with: Ci = Runoff coefficient per landuse

Ai = Area of each type of landuse

In more details, the stages of data processing and analysis using GIS are presented in Figure 4.

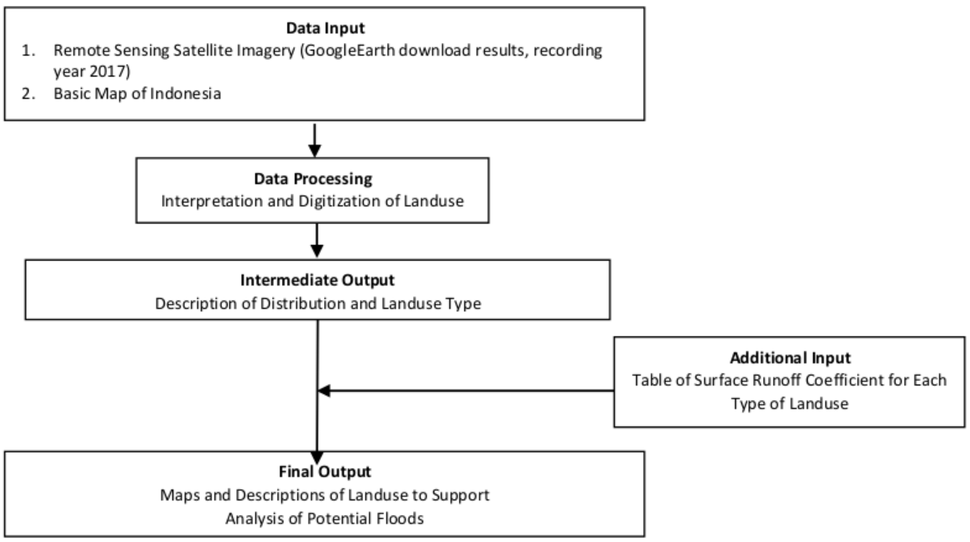

Figure 4. Flowchart of Research Analysis Method

C. Result and Discussion

1. *Interpretation of Landuse*

Identification of the landuse in this study uses the 2017 recording satellite imagery downloaded from the GoogleEarth application. The image is then interpreted manually using ArcGis mapping software. Based on the results of landuse interpretations, in general, there are differences in variations between the districts within the Yogyakarta City area and the districts outside it. On the interpretation scale of 1:25,000, the landuse in all districts in Yogyakarta City area can only be generally divided into two types, namely developed and undeveloped land. The developed land includes settlements and others (shops, offices, education, warehousing). Undeveloped lands are generally in the form of yards, parks, gardens, cemeteries, and fields in relatively small areas. Meanwhile, landuse in the districts outside Yogyakarta City looks more varied with areas that are still easy to delineate. These landuses include forests, farms/fields, rice fields, settlements, industry, cemeteries, airports, and open land/fields. The distribution of types and area of landuse as an interpretation result is presented in Table 3 and Table 4.

Table 3. Distribution of Types and Area of Landuse in Research Area Districts in Sleman and Bantul Regencies

Regency	Type and Area of Landuse (Ha)								
	District	Forest	Farm/ Field	Ricefield	Settle ment	Industry	Cem etery	Air port	Open Space
Sleman	Depok		29.48	422.34	2626.25			396.39	
	Gamping		262.24	2076.26	568.90	15.43			
	Godean		91.28	1344.16	1238.76				
	Kalasan		4.58	1755.90	1701.69	10.28			
	Mlati			984.52	1902.25				
	Ngaglik		5.35	3179.62	548.61				
	Ngemplak			2213.23	1524.73	4.97			
	Turi	715.15	2394.70		861.08				
	Pakem	1538.77	714.71	1859.57	991.68	2.70			215.11
	Cangkring	2494.97	51.53	1243.43	693.03				62.76
	Seyegan		57.54		1139.22				
	Sleman			1732.91	1381.73				
Bantul	Bangunta			1166.52	1730.93				
	Sewon			1174.23	1609.07				
	Kasihan		16.27	1167.94	1969.62		8.35		

Source: Data Processing (2018)

Table 4. Distribution of Types and Area of Landuse in Research Area Districts in Yogyakarta City

District	Type and Area of Landuse (Ha)	
	Developed Land (Settlement, Office, Education, Warehouses, Trading and Service)	Undeveloped Land (Park, Field, Cemetery, Farm/Yard)
Wirobrajan	102.52	83.87
Umbulharjo	357.31	225.72
Tegalrejo	216.62	106.84
Pakualaman	55.11	24.15
Ngampilan	47.98	27.04
Mergangsan	158.97	92.68
Mantrijeron	208.15	70.07
Kraton	122.19	38.76
Kotagede	238.23	85.58
Jetis	109.45	71.96
Gondomanan	90.13	14.16
Gondokusuman	311.56	111.42
Gedongtengen	81.36	11.98
Danurejan	82.60	13.13

Source: Data Processing (2018)

2. *Assessment of Landuse Runoff Coefficient*

Assessment of runoff coefficient in the study area shows that the lowest value of runoff coefficient is in Pakem District, which is 0.21. Meanwhile, the highest runoff coefficient is in Gedongtengen District, which is 0.69. The result of landuse interpretation shows that Pakem District has forest land as much as 28.91% (1,538.77 Ha) and rice fields as much as 34.94% (1,859.57 Ha). Both landuses contribute positively to the runoff coefficient so that around 79% of rainwater in Pakem District has the opportunity to be infiltrated below the land surface and has the potential to become a groundwater reserve. Meanwhile, only 21% has the potential to become runoff water (and also vapour). In Gedongtengen District, the composition of landuse includes 87.16% (81.36 Ha) of developed land and 12.83% (11.98 Ha) of undeveloped land. With this landuse composition, 69% of rainwater (precipitation) falling in the area has the potential to become surface runoff and vapour (through evaporation and evapotranspiration process) and only 31% has the potential to be infiltrated below the surface.

Referring to the Regulation of the Director General of RLPS Number: P.04/V-SET/2009, the results of the study of runoff coefficient values in the study area are grouped into 3 categories, namely good ($C < 0.25$), moderate ($0.25 \le C \le 0.50$), and bad ($0.51 \le C \le 1.00$). Based on this category, of the 29 districts included in the scope of the study, 3 districts have good runoff coefficient categories, 10 with moderate categories, and 16 others are bad. However, seen from the aspect of area, the moderate category covers the largest area.

As presented in Table 5, the districts with good categories are Ngaglik, Pakem, and Cangkringan Districts. The three districts are administratively located in Sleman Regency, while based on watershed concept, they are in upstream areas. Based on the runoff coefficient value obtained, the role of the three districts as water catchment areas is still functioning well, i.e. more than 75% of falling rainwater can still be infiltrated. Districts that are included in the moderate category are Gamping, Godean, Kalasan, Ngemplak, Turi, Seyegan, Sleman (Sleman Regency), Banguntapan, Kasihan, and Sewon (Bantul Regency). The districts are partly located in the upstream and partly in the middle part of the watershed. Meanwhile, the areas included in the category of bad runoff coefficient are all districts in Yogyakarta City area along with Depok and Mlati Districts in Sleman Regency. Spatially, the distribution of runoff coefficient categories in the study area is presented in Figure 5.

Table 5. The Result of Landuse Runoff Coefficient Assessment in Research Area

City/Regency	District	C-Value (Runoff Coefficient)	Grade C
Sleman	Depok	0.55	Bad
	Gamping	0.25	Moderate
	Godean	0.34	Moderate
	Kalasan	0.39	Moderate
	Mlati	0.54	Bad
	Ngaglik	0.22	Good
	Ngemplak	0.36	Moderate
	Turi	0.25	Moderate
	Pakem	0.21	Good
	Cangkringan	0.23	Good
	Seyegan	0.36	Moderate
	Sleman	0.39	Moderate
Bantul	Banguntapan	0.45	Moderate
	Kasihan	0.45	Moderate
	Sewon	0.50	Moderate
Yogyakarta	Wirobrajan	0.53	Bad
	Umbulharjo	0.56	Bad
	Tegalrejo	0.58	Bad
	Pakualaman	0.60	Bad
	Ngampilan	0.57	Bad
	Mergangsan	0.57	Bad
	Mantrijeron	0.62	Bad
	Kraton	0.63	Bad
	Kotagede	0.62	Bad
	Jetis	0.55	Bad
	Gondomanan	0.68	Bad
	Gondokusuman	0.62	Bad
	Gedongtengen	0.69	Bad
	Danurejan	0.68	Bad

Source: Data Processing (2018)

Within the scope of Yogyakarta Urban Area, areas that have a good runoff coefficient category cover an area of 1,368 Ha, a moderate category of 10,196, 43 Ha, and a bad category of 8,087 Ha. The good category is the Yogyakarta Urban Area which is located in parts of Ngaglik District, while the bad category covers the entire Yogyakarta City area as well as Depok and Mlati Districts. Depok and Mlati districts are part of KPY with the location directly adjacent to the city of Yogyakarta to the north. Thus, it is very natural that the two districts experience the development of built up land as a consequence of the development of the City of Yogyakarta and result in a high coefficient of runoff. This is in accordance with the research of Wijaya and Umam (2015) which states that the development of land built in the city of Yogyakarta in 2003-2013 has a rate of 329 ha/year with its development center to the northeast of the city of Yogyakarta, which is the area around Gondomanan District and Depok District. In addition, Mlati District also has an area with a probability index of 0.9 (close to 1) which means that the more likely the area is predicted to turn into developed land. Meanwhile, the results of the runoff coefficient assessment indicate that Gondomanan District has the second highest C value in Yogyakarta City.

Yogyakarta Urban Area has spread and experienced an expansion, marked by physical changes in landuse or referred to as the phenomenon of spatial urbanization. The physical form of the Yogyakarta Urban Area has changed, that is, the physical boundaries of the city are outside the Yogyakarta City Administration or often referred to as Under Bounded City (Selang, et al., 2018). Besides Mlati and Depok Districts, the areas that became the physical expansion of the City of Yogyakarta were Gamping, Godean, Ngaglik, Ngemplak, Banguntapan, Sewon, and Kasihan. Wijaya and Umam (2015) suggested that in 2013-2023 the center of the development of the developed land was predicted to be in the southwest direction of Yogyakarta City, namely around Kasihan and Mantrijeron Districts. Along with urban physical development, the seven districts currently have a runoff coefficient in the moderate category. Meanwhile, Mantrijeron District ranks the fourth highest runoff coefficient in the city of Yogyakarta.

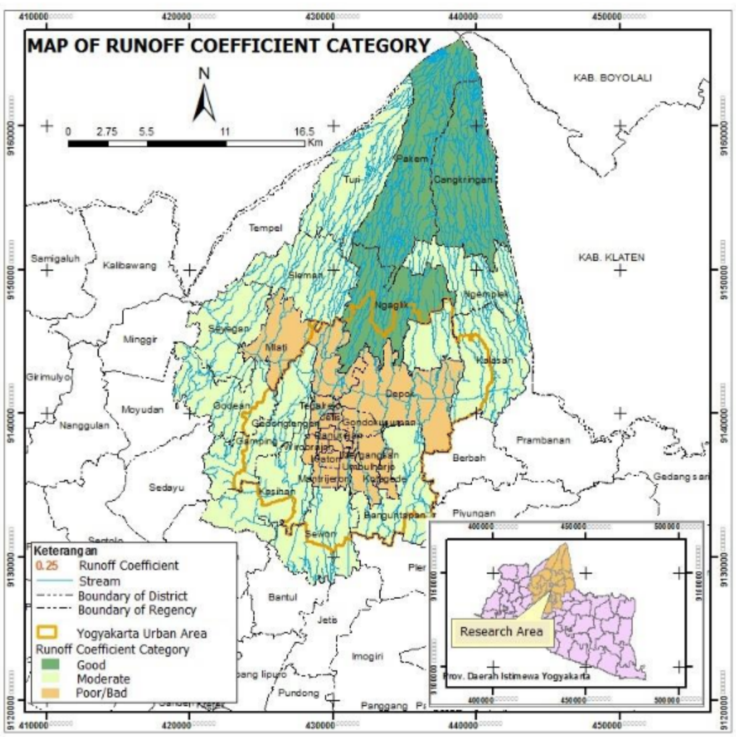

Figure 5. Distribution of Runoff Coefficient Category in Research Area

With the composition of the existing runoff coefficient, it can be assumed that the occurrence of floods and puddle in the Yogyakarta Urban Area is more triggered by the factor of limited infiltration capacity in the Yogyakarta Urban Area itself, especially in the Yogyakarta City area, although the upstream area also continues to contribute to the potential for flooding. Non-structural efforts in the form of landuse control in the study area are needed to reduce the increase in runoff coefficient. For upstream and suburban areas, landuse control is needed to control land conversion from undeveloped to developed so that its function as a recharge area is maintained and even improved. However, the physical development of the Yogyakarta Urban Area is difficult to avoid given its strategic function. For urban areas where built up land already dominates, environmental engineering efforts are needed in order to increase the capacity of rainwater catchment and storage so that surface runoff that has the potential to cause flood and puddle can be minimized. Rahardian and Buchori (2016) mentioned several efforts to conserve water resources related to handling surface runoff, namely the development of Green Open Space, the development of rainwater infiltration wells, the application of Biopori Absorption Hole technology, and the combination of the three conservation efforts. The development of green space is an effort that is closely related to the allocation of space and landuse. Meanwhile, Kodoatie (2013) mentioned the structural methods that can be used to control floods include dams / reservoirs, retention ponds, check dams, river slope building, and retarding basin.

D. Conclusion

Variation in landuse affects the runoffcoefficient in the study area, which ranges from 0.21 to 0.69. From these variations, all districts in Yogyakarta City and Depok and Mlati Districts in Sleman Regency are in the bad category (C value = 0.51-1.0). This value means that more than 50% of rainwater will become surface runoff (and vapour). Meanwhile, other districts which are on the outskirts of Yogyakarta City and have an area designated as the Yogyakarta Urban Area have a moderate category (C value = 0.25-0.50) which means that 25-50% of the rainwater that occurs will become surface runoff . With the composition of the runoff coefficient, it can be assumed that the occurrence of floods and puddle in the Yogyakarta Urban Area is more triggered by the factor of limited absorption capacity in the Yogyakarta Urban Area itself, especially in the Yogyakarta City.

The direction of Water Resources Conservation in the study area is to at least maintain the condition of the runoff coefficient in the upstream area of the Yogyakarta Urban Area which includes Ngaglik District, Pakem District, and Ngemplak District by increasing landuse control so that natural water spaces are able to accommodate rainwater optimally. For Ngemplak, Turi, and Sleman Districts, environmental engineering needs to be carried out to develop artificial catchment capacity (flood control infrastructure) in order to increase rain catch capacity, considering the high runoff coefficient category (moderate category).

Meanwhile, in Yogyakarta Urban Area itself, in addition to increasing spatial control, it is also necessary to develop the capacity of artificial rain catchment space. However, because the land in Yogyakarta Urban Area, especially those in the Yogyakarta City area is very limited, innovation and variations in the development of rain catchment capacity are needed.

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