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Evaluation of Greenspace as Phytodrainage in Sidoarjo

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ABSTRACT

This study aimed to determine the ability of greenspace for rainwater runoff reduction in the Pucang watersheds Sidoarjo Regency. Methods consisted of descriptive analysis qualitative and quantitative. The results revealed the existing greenspace area of 60.24% could reduce rainwater runoff by 42.98%. Greenspace function as phytodrainage for Pucang watersheds effectively reduce rain water run off in upstream section, which characterized by a sandy loam soil, but was less effective in the downstream, which composed of muddy clay soil.
KEYWORDS: phytodrainage, greenspace, runoff reduction

INTRODUCTION

The landscape of Sidoarjo Regency especially in urban area is flat and undulating terrain. In hydrology system, this urban region is affected by Kapetingan watershed, which is divided into four sub-watersheds. On the northern there are Pucang watershed and Kemambang watershed, while Sekardangan sub-watersheds and Sidokare sub-watersheds on the southern. Pucang watersheds located on the upstream side has the most extensive drainage system and become the main channel systems in Sidoarjo urban drainage systems. Pucang watershed has significance especially in terms of protection of water function. The growth of industrial estates, housing, and the development of new cities in the northern part of the urban Sidoarjo, especially in the upstream (Pucang watershed) has been triggering change in land use from agricultural land into built area. Agricultural land in Sidoarjo Urban Area North Rayon currently of 3,186 hectare and estimated to drop to 2,058 ha in 2020 [1] While the rice field area in Sidoarjo currently is listed 17,205 hectare [2] decrease from 29,000 ha in 2009[3].

The Change of vegetation land cover in the upstream area into built area impact the fluctuation runoff, transport of sediment and dissolved material in the downstream area thus increase flood occurrence. Genesis flood in 2013 in Sidoarjo urban noted there were 23 inundated villages with approximate area 424.32 hectares. At the beginning of 2016 a number of puddle points in urban areas has increased from the previous year. Village flooded were Bluru, Pucang, Sidoklumpuk, and Sidokare. The results of data collection onDisaster Management Agency Sidoarjoregarding floods on February 5 to 13, 2016 the number of affected households reached the 49,979 families, scattered in 11 districts and 62 villages [4].

In city planning, greenspace used as a development controlling of the city.Greenspace is the government's efforts to protect vegetation reduction through local regulations in urban area. The effectiveness of greenspaces for runoff reduction is highly dependent on physical factors and characteristics that exist in the local environment. To maximize the effect of urban greenspaces to reduce flooding need to understand the local characteristics. In addition, the provision of greenspaces was also related to the position of a city in watershed.Theconcept of river basin in an ecosystem integrates components of soil, vegetation and water/ river becomes a unity in realizing sustainable development [5].

Greenspace application has been increasingly identified as a method for runoff reduction and reduces negative impact of urbanization for hydrological cycle in urban areas [6]. Greenspaces reduce more than 50% the possibility of urban flooding in Seoul, depending on the size and location of greenspace[7]. The application of greenspaces in residential areas Manchester, UK by 10%, reduce rainwater runoff by 4.9%, even if all area consists of trees with the same amount area reduce rainwater runoff by 5.7% [8].

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The new paradigm of urban drainage drainage system put as urban infrastructure is based on environmentally friendly or sustainable drainage concept. The comprehensive and environmentally friendly drainage system is mandated in the Minister of Public Works regulation No. 12 / PRT / M / 2014 on the Implementation of Urban Drainage Systems, strive for rain water that falls can be held in advance, thus increasing infiltration into the soil in natural and artificial way. Physical form of natural drainage infiltration technology is permeable ground cover, which is a greenspace (phytodrainage).

METHODS

Study Area

The study area of this research lies between 112.50 to 112.90 East Longitude and 7.30 until 7.50 South latitude, an area between the Delta Brantas in Porong River in the south and the Surabaya River in north. Geographically, the highest absorption rate is in the west, while the lowest infiltration rates the lowest in the eastern part. Based on the distribution rate infiltration, Pucangwatershed divided into three zones of absorption, quick infiltration zone (≥ 12.5 cm / h), somewhat faster (6.25 to 12.5 cm / hour) and the infiltration zone is rather slow (≤ 0.5 to 2 cm / h) [9]. Map of Drainage Systems North SidoarjoArea which became part of the drainage system Sidoarjo can be seen in Figure 1.

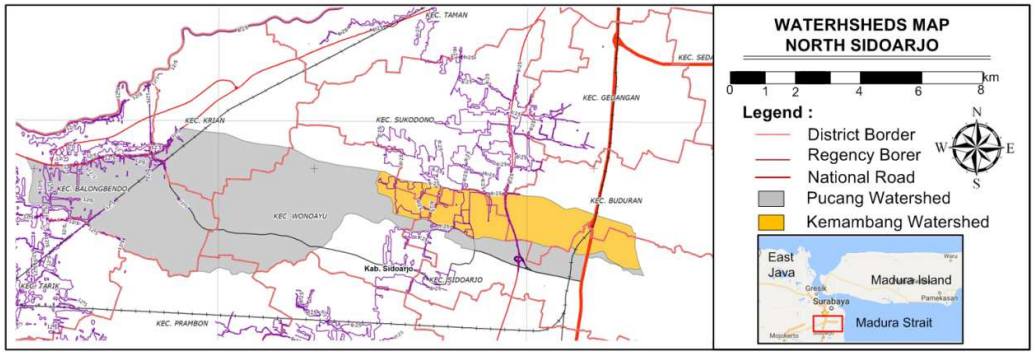

Figure 1Watersheds Map Drainage Systems North Sidoarjo Area

Methods

The method used in this research is descriptive analysis method qualitative and quantitative. Evaluation phase begins with hydrology analysis. The second stage perform the zoning study area to facilitate analysis. The third phase identifies existing greenspace in the study area base on area. Identification of greenspace through analysis of high-resolution imagery map Google Earth 2016. Furthermore, the interpretation of a map verified by direct observation in the field and confirm with the relevant agencies. The fourth stage conduct a study of the ecological benefits of greenspace associated with hydrological functions, namely how the potential of greenspaces for runoff reduction which can be calculated using the Darcy formula.

RESULTS AND DISCUSSION

Hydrological analysis

Hydrological analysis aims to determine rainwater flow rate and runoff flow rate to determine the amount of runoff caused by land development activities. Pucangwatershedinfluenced by six (6) rain stations: Ponokawan, Krian, Watutulis, Ketawang, Klagen and Ketintang Station. Rainfall data use last fifteen years data (2001 - 2015). The result of the calculation precipitation plans with Gumbel method for return period of 10 years derived rainfall in the Pucang Watershed of 119.55 mm / day.

Zoning

Pucang Watershed zoning based on the dominance of existing land use. Existing land use is an important factor to be considered in zoning because affect surface roughness and determine the amount of surface drainage coefficient (C), which affects the amount of rainwater runoff.

The uniform of slope in Sidoarjo urban area in is a factor that should not have a significant influence, not to be considered as a variable in the zoning. Factors tidal participated in the classification variables used because most urban zone Sidoarjo is located in coastal areas and give effect to ponding.

PucangWatershed each divided into four (4) zones. The characteristic of each zone in the Pucang Watershed is shown in Table 1.

Table 1: Description of characteristics Zone in PucangWatershed

Zone	Area (m^2)	Altitude (msl)	Slope (%)	Type of Soil and Permeability	Land use
PUCANG WATERSHED					
I	43.097.279,72	4 - 23	<1%	Alluvial soil Rather quickly (6.25-12.5cm/h)	Dominated by Agriculture / technical irrigated fields. Kampong settlement. Highest Vegetation cover.
II	3.014.092,23	4	<1%	Alluvial soil rather quickly (6.25-12.5 cm/h)	Dominated by Settlements with a housing
III	235.943,49	4	<1%	Alluvial soil slower (≤ 0.5 - 2 cm/h)	Mixed a residential, industrial, aquaculture Housing and kampong. Tide and flood-prone area
IV	473.784,58	4	<1%	Alluvial soil Soil Slower (≤ 0.5 - 2 cm/h)	Dominate by Aquaculture SmallVegetationvery small. Tide and flood-prone area

Area and Distribution of Existing Greenspace

In this study, Greenspace is all vegetative cover consists of public greenspaces, private greenspace, farmland and vacant land. Publicgreenspace in PucangWatershedconsistsof garden, green lane street (median roads and borders), cemeteries, sports fields. From on the calculationshowsthat ratio of public greenspace in Pucangwatershed is 1.98% of Pucang watershed area or 557,316.67 m^2. Conditions of greenspace currently are in a state of well-maintained. Implementing agency for maintenance public greenspace is Cleanliness and Landscaping Agency while Irrigation Agency specifically for greenspace of riverzone.

The area of public greenspace in urban areas Sidoarjo still under the minimum rules required is equal to 20%. Land is used as a greenspace is the government's assets and has not increase since 2015. Land constraint is the major problem for increasing greenspace. For current conditions Cleanliness and Landscaping caAgency focused on maintaining and improving the quality of greenspace to revitalize / re-creating the lands that has been planed as angreenspace.The condition of public greenspace in the Pucangand watershed is shown in Figure 2.

River Strip Pucang

Figure 2: Public Greenspace in the Pucang Watershed

Which included private greenspace areparks lane road / street median in the housing area. Implementation of private greenspace on residential in Sidoarjonowdays can only be controlled areas due to the obligation to obtain a Site Plan Permit and Building Permit with must hand over land for public facilities by 40% of the site plan that covers an area of 20% as greenspace. Monitoring changes in land use in the yard of the house, commerce and industry is difficult to do because of the lack of proper inspection. For that reasons, the calculation takes into account only private greenspace area of greenspace, residential area managed by the developer.And from the calculation result shows private greenspace in the Pucang0.48% of the Pucangwatershed area or 222,637.95 m^2. Generally, the condition of greenspace in a residential area is shown in Figure 3.

Garden in Citra Garden | Garden in PondokJati | Garden in KahuripanNirwana

Figure 3: Condition of Greenspace in a Residential Area

Private greenspace, farmland and vacant land is potential greenspaces.Developers are tend to doing a land conversion if not controlled properly. Greenspaceagriculture fields / farms have the largest area. Current agricultural land in the district of Sidoarjois still owned by individuals without any effort to control / protection of the local government. This condition is critical for conversion of agricultural land as housing, given the high development of housing needs in Sidoarjo and the current development tends to be shifted from Zone 2 and Zone 3 Pucang already crowded to the west (Zone 1 Pucang).

Overall the area of greenspace in the Pucang watershed is amounting to 28,204,808.66 m^2 (60.24%.) The areagreenspace that exists today in the Pucang watershed already exceed the minimum threshold is 30%, appropriate reference standards set by the Law on Spatial Planning No. 26/2007.

Table 2: Area of greenspace in Pucang watershed

Vegetation Cover	Zone 1 Pucang		Zone 2 Pucang		Zone 3 Pucang		Zone 4 Pucang	
	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%
Public Greenspace	388,896.89	0.9	130,290.91	4.32	16,391.11	6.95	21,737.76	4.59
Settlement Garden	27,500.00	0.06	156,477.00	5.19	-	-	38,660.95	8.16
Agriculture	22,691,517.28	52.65	-	-	-	-	-	-
Fields	3,191,529.88	7.41	-	-	-	-	-	-
Bare	1,513,751.46	3.51	1,050.39	0.03	27.005.03	11.45	-	-
Total	27,813,195.51	64,54	287,818.30	9.55	43,396.14	18.39	60,398.71	12.75
Greenspace Area in Pucang Watershed (m^2)	**28,204,808.66**		**Greenspace Area in Pucang Watershed (%)**				**60.24**	

Map of the distribution of greenspace in the Pucang watershed areais shown in Figure 4.

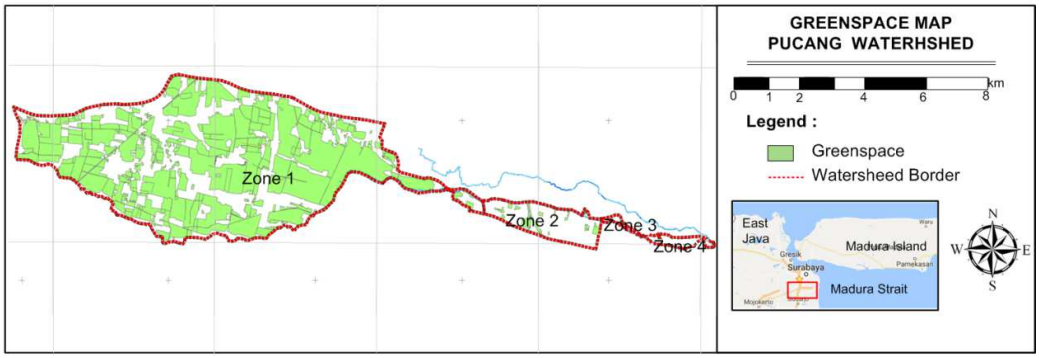

Figure 4 : Distribution of Greenspace in the PucangWatershed

Effect of GreenspaceTowards Flow Surface

Affecting factors the water gets a chance infiltration is consisting of surface roughness, topography and rainfall intensity, which is part of the runoff. Table 3shows the relationship between the effect of land cover conditions on the runoff, flow travel time and magnitude of runoff/ flood discharge in Pucang Watershed.

Table 3: Relationship Between Greenspaces with Surface Flow Pucang Watershed

Zone	Slope (%)	Land use in 2016				
		Greenspace Area	C	to	vo	Qr
Pucang		(%)		(minutes)	(m/s)	(m^3/s)
1	0.05	64.54%	0.42	487.81	0.22	39.06
2	1.34	9.55%	0.70	22.60	0.27	16.70
3	0.51	18.39%	0.70	26.36	0.16	1.74
4	0.33	12.75%	0.13	81.34	0.06	0.50
Total		**60.24%**	**0.44**			

Area of greenspace in each zone give effect to the value of drainage coefficient "C". Zone 1 Pucang expanses of the largest green area in the form of agricultural land in the amount of 64.54% has the smallest flow coefficient of 0.42 compared to the other two zones that is Zone 2 and Zone 3 is the largest land use as residential / settlements. In Zone on Zone 4 magnitude spacious greenspace does not affect the substantial value of the coefficient "C", as it is the Zone 4 Pucang majority of pond land use is considered equal to the storage pond for runoff (drainage coefficient = 0.01 (no runoff).

The slope of the land in PucangWatershedis uniform ≤ 1%.The existence of greenspace is not a significant effect on the change of pace in the runoff. Table 4 shows that all the zones in PucangWatershed with coefficient C which is different turns all zones have nearly uniform speed that isequal to 0 m/s. Drainage speed value equal to 0 m /s is a value so low that it is already possible natural potential of rainwater have a long time to stay and have a great opportunity to infiltrate.

Effect of GreenspaceAgainst Infiltration Capacity

One of the potential of greenspaces for the environment according to Regulation of Ministry of Public Work 12/2014 is to reduce flooding and groundwater recharge through infiltration process. In general, the potential of reducing inundation is the ability to reduce the discharge of rain and into the drainage channel through the process of infiltration by greenspaces. The physical condition of the soil is much influence on the ability of greenspaces in improving the infiltration capacity.

The ability of soil for doing soil drainage is a parameter that describes how much rainwater can be infiltrated. Soil contained in the greenspaces that become the object of study is an alluvial soil. Type of alluvial soil is sandy clay / muddy in the USDA soil classification soil types B and C categories which have the capacity and infiltration rate rather fast and low.

Pucang Watershed has rain intensity of 40,49 mm/hour. Zone 1 and 2 Pucang have rather rapid infiltration rate that is equal to 125 mm/ hour. While other zones Pucang 3 and 4 have the infiltration rate of 20 mm/ hour. The infiltration rate in Zone 1 and 2 Pucanghave rain intensity value smaller than the infiltration capacity, so that the actual infiltration rate equal to the intensity of the rain. Runoff occurs when the rate of rainfall intensity is greater than the infiltration capacity. So that in Zone 1 and 2 Pucang has not become a potential rainwater runoff if the land cover is maximized as absorption. While in Zone 3 and 4 Pucangrainfall intensity value is greater than the infiltration capacity that could potentially occur inundation.

In watershedsthe amount of infiltration flowrate is identical with the area of absorption in the form of a greenspace /green land cover. Assuming that the maximum capacity of infiltration occurs, the amount of discharge of infiltration in each zone can be calculated. The following is an example calculation of infiltration discharge in Zone 1 Pucang.

The Data :

Soil Permeability(K) = 125 mm/hour

Fully plant coverage of greenspace = 27,813,195,51 m^2

then, Infiltration flowrate can be calculated by:

$$Qi = K.i.Av$$

$$Qi = 125\frac{mm}{Hour} * 1 * .27{,}813{,}195.51\ m2$$

$$Qi = 965.74\ m3/s$$

The results of calculations for each zone in PucangWatershedcan be seen in Table 4.

Table 4: Result of Calculation Infiltration Flowrate Pucang Watershed

Zone	Zone Area	Greenspace Area	% Greenspace	Soil Permeability (K)	Head loss (i)	Infiltration Flow rate (Qi)
Pucang	**m^2**	**m^2**		**(mm/hour)**	**(m/m)**	**m^3/s**
1	43,097,279.72	27,813,195.51	64.54%	125	1	965.74
2	3,014,092.23	287,818.30	9.55%	125	1	9.99
3	235,943.49	43,396.14	18.39%	20	1	0.24
4	473,784.58	60,398.71	12.75%	20	1	0.34
	46,821,100.02	**28,204,808.66**				

Water Balance

Quantitative estimates of the hydrologic cycle can be expressed based on the principle of conservation of mass, known as the water balance equation. In general, the water balance equation is as follows:

(Received Water) - (Released Water) = (Stored Water)

Evapotranspiration is one component of the released water. Evapotranspiration value depends on the type of plant. As a general overview of the value of evapotranspiration by plants in a greenspace used type of rice plant, with consideration of rice is the main vegetation in the PucangWatershed. Value of evapotranspiration average rice plants using the research results of the Faculty of Agriculture IPB in irrigated areas in the rainy season *SeputihWay* by 3.4 mm /day [10]

In areas with large irrigated, the addition of water is influenced also by factors of irrigation. The purpose of irrigation is to provide additional water to rain water and provide water to the crops in adequate amounts and at the required time [10].Calculation of irrigation water is shown in Table 5.

Table 5: Irrigation Calculation of Pucang Watershed

Periode	Zone I Pucang			
	Crop Coefisien	**% Land Distribution**	**Rice Fields (hectare)**	**CAR Rice Fields work**
Rice field works	6	30%	680.75	4,084.47
Seeding	20	20%	453.83	9,076.61
Planting	4	40%	907.66	3,630.64
Young cane/ bibit	1,5	10%	226.92	340.37
Old cane	0	-	-	-
Crops	1	100%	319,15	319.15
Crop Area Relative (CAR)				**17,451.25**
Irrigation water demand (m^3/dt) * Crop Coef = 0.4			**6,980.50**	
Left over Irrigation with (m^3/dt) water demand efisiency =75%			**1,745.12**	
Fields area in Zona 1 Pucang = 22,691,517.28 m^2 , Crops area = 3,191,529.88 m^2				

From the calculation of rain, infiltration and irrigation, it can be calculated water balance in the watershed Pucang as shown in Table 6 and Figure 5.

Table 6: Calculation Water Balance Pucang Watershed

Water Balance	Source			Pucang 1	Pucang 2	Pucang 3	Pucang 4
Received water	Presipitation	(P)	(m^3/s)	484.71	33.90	2.65	5.33
	Leftoverirrigation	(Ir)	(m^3/s)	1,745.12	-	-	-
	Runoff previous zone	(Qn)	(m^3/s)	-	1,262.93	1,286.83	1,289.24
Stored water	Greenspace infiltration	(i)	(m^3/s)	965.74	9.99	0.24	0.34
Released water	Evapotranspiration	(Et)	(m^3/s)	1.16	0.01	-	-
	Runoff	(Q)	(m^3/s)	1,262.93	1,286.83	1,289.24	1,294.23

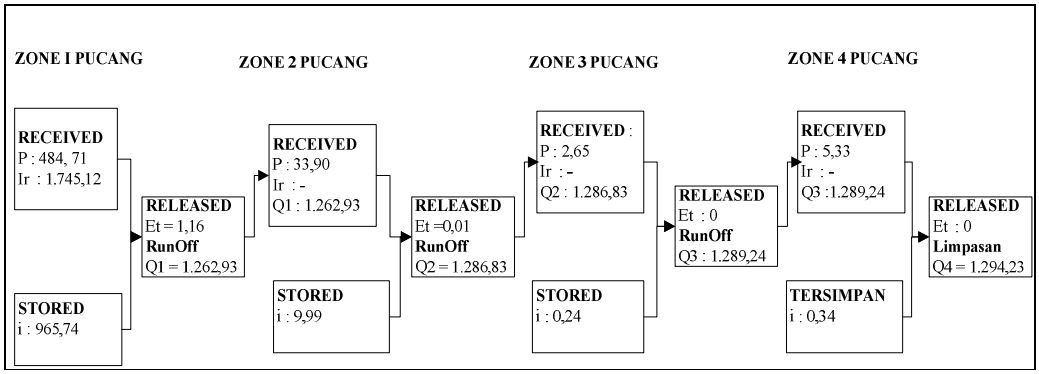

Figure 5: Water Balance Pucang Watershed

By calculating the potential of greenspace as a whole in Pucang Watershed, the potential of greenspace as phytodrainage is 42.98%. The ability of existing greenspace within infiltrating rainwater is very effective, because it has the same value with the rainwater flowrate, especially in watershed Pucang. Influence of leftover irrigation is very large and has the potential make channel overflow.It should be considered to make the storage pond for leftover irrigation water that does not meet the capacity of the existing drainage channels and can be reused for irrigation and groundwater recharge. Potential greenspace as runoff reduction (phytodrainage) overall in Pucang Watershed is shown in Table 7.

Table 7: Greenspace Potential as Phytodrainage

Water Balance	Source			Pucang	
Received water	Presipitation	(P)	(m^3/s)	526.59	23.18%
	Irrigation Effluen	(Ir)	(m^3/s)	1,745.12	76.82%
Stored water	Greenspace Infiltration	(i)	(m^3/s)	976.31	42.98%
Released water	Evapotranspiration	(Et)	(m^3/s)	1.17	0.05%
	Runoff	(Q)	(m^3/s)	1,294.23	56.97%

The illustration of water balance shown in figure 6

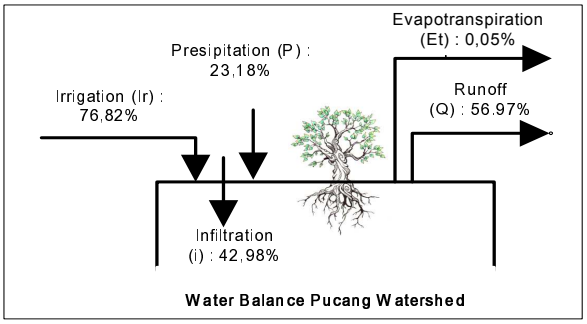

Figure 6: Scheme of Pucang Watershed Water Balance

Potential evapotranspiration of greenspaces value is very small, so it does not contribute during a short duration rain. Thus it can be stated that the ability of greenspace as phytodrainage is the ability of greenspace in maximizing soil infiltration capacity by enlarging the porosity of the soil.

CONCLUSION

The existing greenspacehas a potential capability as a phytodrainagefor rainwater runoff reducing by 42.98% in the Pucangwatershed. Functions as phytodrainage in Sidoarjo can effectively reduce runoff in Zone 1 and Zone 2 on the PucangWatershed which have sandy loam soil types, but is less effective in Zone 3 and Zone 4 Pucang Watersheds which have muddy clay soil types.

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