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Research Article

Buffering capacity of paddy field as the reservoir of rainwater and surface runoff in the Lowokwaru subdistrict, Malang, East Java

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Abstract: Paddy fields produce ecological services that improve environmental quality in urban areas, one of them was flood control through retaining rainwater and surface runoff within the embankment of paddy field. The ability to retain water is known as the buffering capacity (BC), which is the function of soil moisture, embankment height, water inundation and rice-plant interception during the growing periode. The intermitten system of water inundation applied by farmers resulted in changes of the BC on daily basis. The calculation of BC was divided into five categories for accuracy, which were : (1) BC during the Harvest; (2) BC with inundation at vegetative and generative phase (VGG); (3) BC with inundation during Land Preparation and Planting phase (OTTG); (4) BC without inundation during the vegetative and generative phase (VGTG); and (5) BC without inundation during the land preparation and planting phase (OTTTG). The purpose of this research was to measure potential buffering capacity of paddy field in Lowokwaru Subdistrict and to estimate amount of rainwater and surface runoff which could be accommodated within the buffering capacity. The average of daily BC in seven different villages were 1,650.81– 3,961.81 m^3/ha and the total BC for 241 paddy field was about 823,156.36 m^3. It was only a small percentage of average daily BC filled by rainwater (14.07-33.31%) and left the rest to be filled by surface runoff water. The paddy field of 241 ha in Lowokwaru Subdistrictis was capable to receive surface runoff from surrounding areas up to 1,698.66 ha.

Keywords: *buffering capacity, paddy field, rainwater*

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Introduction

Among many man-made ecosystems that exist today, one which is quite unique, is paddy field, that is used for rice cultivation. Paddy field as an ecosystem holds several functions which includes regulation function, habitat function, production function, information function and carrier function to service living needs for human beings (De Groot, 2006). Paddy fields function as carrier to human's need for food, especially rice, which developed by permanently converting existing natural ecosystem into this specific man-made infrastucture to achieve food suficiency. But as time elapsed, paddy fields became advanced man-made ecosystems that develop into multi-function ecosystem which provides other benefits for human beings (Huang, et al., 2006; Matsuno et al., 2006). Environmental services produced by paddy fields are considered to be public goods, which are beneficial to society and their surrounding (Iiyama et al., 2005). The 2005 Millenium Ecosystem Assessment reported that the ecosystem services of paddy fields generate many positive impacts to the environment and socities, among others are: maintaining several ecological processes such as micro climate, flood mitigation, run-off and drainage system regulation, and groundwater recharging (Wu et al., 2001; Liu et al., 2004; Imaizumi, et.al. , 2006; Tanaka et al., 2010). The existence of paddy field in urban areas increasingly becomes significant for not only produces food, but also it maintains good quality of living environment and produces many external benefits indirectly (Yokohari et al., 1997; Matsuno et al., 2007). The ability to reduce risks of or control flood is one of the many positive impacts that paddy fields contribute to living environments (Yoshikawa et al., 2010; Sudrajat, 2015). The structure of paddy fields that have flat surface and enclosed by embankments made them able to function as small dams that retain rainwater and therefore reducing the chance of flood occurance (Yamamoto et al., 2003). The ability to retain rainwater is originally aimed to supply sufficient water for rice plants at growth stage (Yoshikawa et al., 2010). Thus, to a certain point, paddy fields is an analogy to wetlands (swamp) as parking spaces for rainwater (Natuhara, 2013). At the occurance when rainwater exceeds the height, of paddy fields' embankment, then they no longer function as water reservoir (Odum,1995). Therefore, the ability of paddy fields to retain rainwater and/or surface run-off is only useful when rain occurs as to when it can prevent flood in lower areas or downstream (Masumoto et al., 2006).

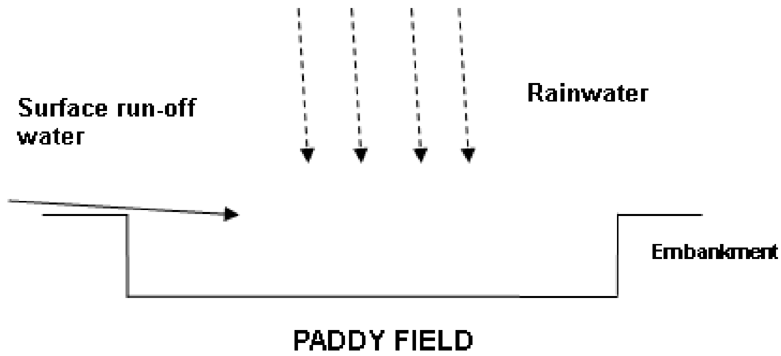


Figure 1. Paddy field as reservoir for rainwater and surface run-off

The rapid rate of economic growth in the City of Malang resulted in a rapid change of land utilization that followed the shifting needs of city's populace. Paddy fields in urban areas are very susceptible to convertion into built areas (Su et al., 2011; Song et al., 2015). Land conversion will change soil biophysical, rice production and decrease enviromental qualities (Irawan, 2005; Nurliani and Ida-Rosada, 2016). In general, land conversion will alter the hydrological cycle of ground and surface water which includes water quality and flood-water debit (Meyer dan Turner II, 1992'; Poulard et al., 2010.). The research in Lowokwaru Subdistrict, City of Malang, was aimed to spesifically measure daily potential buffering capacity of paddy fields, and to estimate the volume of rainwater and surface run-off water to fill its maximum buffering capacity.

Materials and Methods

Research location

The research was conducted in areas of paddy fields of Lowokwaru Subdistrict, City of Malang, East Java. The total area of Lowokwaru Subdistrict is estimated 2,090 hectares, divided into 11 villages. There are only 7 villages that uphold Paddy field in Lowokwaru Subdistrict with total area of 241 hectares.

Research method

The research was conducted using quantitative approach through survey method. Data used in this research were primary and secondary data. Primary data were collected on location by direct measurement (height of embankment and water-flooding by farmers) and direct farmers interviews (duration of water-flooding, and cultivation system). Descriptive analysis was used as method of explaination of research result. Paddy fields's buffering capacity to retain rainwater was calculated using the following mathemathical formula (calculated in days) :

WPi = [(TP-TG) + KI]

Where : WPi = potential buffering capacity of paddy field (m^3); TP = embankment height (m); T

= water-flooding height (m); KI = interception capacity (m)

At research location, the average duration and height of water-flooding conducted by farmers are relatively similar in all village, which is 4 cm. The interception capacity of plant varies depending on plant types, planting distance, and their growth phases (Slamet et.al., 2013). The embankment heights were different across seven villages, as shown in Table 1.

The average of daily buffering capacity was calculated by totaling the values of buffering capacity in each category which had been multiplied by the number of days in corresponding category. Then the total value will be divided by the number of planting days per season. Rice variety used by farmers in research areas is Ciherang (100-110 day-old), therefore the average of planting season in Lowokwaru Subdistrict reaches 124 days.

Table 1. The Average of embankment height in villages of the Lowokwaru subdistrict.

Village	Acreage of Paddy Field (ha)	Average of Embankment Height (m)
Tasik Madu	131	0.41
Tunggul Wulung	36	0.35
Tunjung Sekar	32	0.30
Mojolangu	12	0.28
Jatimulyo	11	0.25
Merjosari	12	0.21
Tlogomas	7	0.18
Average	-	**0.28**
Total	**241**	-

The daily paddy fields' buffering capacity was calculated based on combination of water-flooding height, variation of plant canopy and soil condition. In single planting season, generally, there are three soil condition of the paddy field i.e. : (1) the situation when water-flooding occurs at 4-cm deep; (2) the situation water recedes down to soil surface; (3) the situation when soil is dry. The two situations when paddy fields were water-flooded and at surface level are the situations when soil moisture is at its highest level, hence water infiltration process into the ground will not occur. On the opposite side, when the conditions of soil is dry then infiltration process will take place. Based on those assumptions, the ability of paddy field to retain rainwater is distinguished into five categories below:

- <u>Highest buffering capacity</u> occurs during harvest and fallow period, when the soil is dry (low soil moisture). This condition allow rainwater to infiltrate into ground until water holding capacity reaches its maximum level. Majority of soil type in Lowokwaru Subdistrict is silt-loam which has water holding capacity (whc) in range of 760 – 840 m^3/ha at 40 cm deep. For this research the whc was calculated to be around 800 m^3/ha. This amount then added to the amount of maximum water debit and interception capacity of rice-plant canopy. This stage is refered as <u>**HARVEST**</u>.
- <u>Second highest buffering capacity</u> occurs when paddy fields is not flooded. Thus, the water debit will be in its maximum level. Additional retained rainwater will be gotten when the rice-plant is at vegetative and generative phase (canopy at its peak), then the interception capacity is at work. This stage is referred as <u>**VGTG.**</u>
- <u>Third highest buffering capacity</u> occurs when paddy field is not flooded. Thus, the water debit will be in its maximum level. But there is no additional retained rainwater from canopy of rice-plants. This situation usually happens during land preparation and planting period. This stage is referred as <u>**OTTTG.**</u>
- <u>Fourth highest buffering capacity</u> is when paddy field is not flooded, but paddy is at its vegetative and generative phase. Therefore, there will be additional rainwater retained on canopy amounted to the interception capacity. This stage is referred as <u>**VGG.**</u>
- <u>Lowest buffering capacity</u> occurs when paddy field is water-flooded, but rice-plant's canopy has not emerged, therefore interception capacity will be none. At this stage, water debit is at its minimum level and is referred to as <u>**OTTG**</u>.

Farmers in research locations practice intermitten water-flooding system for irrigation, where the height of water-flooding is maintained simirlar on each application. Farmers decrease water level at vegetative phase of rice-plant for fertilizing, weeding, and pesticide application. At generative phase, farmers flood paddy fields to prevent rodent and pest attack. At harvesting period, farmers dry their field for 6 – 10 days to make rice-grain matured. The height and duration of the water-flooding across sub subdistricts are relatively alike. Table 2 below shows the duration of water-flooding on paddy fields located in Lowokwaru Subdistrict.

Table 2. Duration and Height of water-flooding at Each Rice Growth Stage

Phase	Land-prep		Plant-seed		Vegetative Phase		Generative Phase		Harvest
	*	**	*	**	*	**	*	**	***
Water Depth (m)	0	0,04	0	0.04	0	0,04	0	0,04	0
Duration of inundation (days)	7	4	3	12	15	36	22	17	8
Rice Growth Stage			Early Stage		Young and active Primordia		Panicles Appear		Harvest

Notes: * Without Water : soil wet, maximum soil moisture but paddy fleld not flooded; ** With water : soil is wet, maximum soil moisture and paddy field flooded,; *** Dry : dry soil, minimu soil moisture

To estimate the amount of rainwater and surface run-off water that enters paddy field, the calculation requires a parameter for precipitation intensity that was determined by the following formula:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$$

Where: I = Precipitation Intensity (mm/hour); R_{24} = Daily Maximum Precipitation in 24 hours (mm/hour);
t = Duration of rain (hour)

Result and Discussion

Buffering capacity of paddy fields in Lowokwaru subdistrict

The final stage of hydrologic cycle is when precipitation reaches the surface of the earth. The precipitation that reaches vegetated land surface, such as forest or agricultural land, will be restrained by plants' canopies (leaves, branches, and trunks) before it finally reach the land surface. After reaching the surface then some rainwater penetrates into the ground through soil pores as some others becomes surface run-off. Rainwater which is restrained by plants' canopy is known as interception. The larger plant's canopy the more interception takes place. A natural forest has interception and stem-flow capacity as much as 11.4 % and 1.4 %, as the remaining 87.2 % falls to surface then penetrates into the ground; as for the interception capacity of crop plants is affected depend by type of plants and their growth phase (Asdak, 1995). When rainwater restrained by canopy, it experiences reduction of speed and volume as it reaches land surface; thus it lessened the potential damage caused by precitations. On crop-plant cultivation, the absence of stem-flow and surface litter cause rainwater to directly hit the grown at damaging speed which likely to cause erosion of soil (Slamet et al., 2013). The amount of water restrain on plants' canopies, stems, and branches (also known as canopy storage capacity) is determined by shape, density, and vegetation texture. Rice plants have structure of leaves that is formed in diversed shape, orientation, and size (in quantity and weight) depends on varieties (Makarim dan Suhartatik, 2009). Leaves of reice-plants grow on stem in alternating arrangement, one on each joint. With such arrangement, capacity interception of rice-plants canopy is relatively limited, which is 0.003 as opposed to 0.035 for forests, or 0.025 for mixed garden (Watung et al., 2003). Slamet et al. (2003) stated that irrigated paddy field with continous planting pattern within one year have lower level of ground-water infiltration when compared to alternating planting pattern (rice-plant – other crops) or rice-plant fallow period planting pattern.

The latter two planting patterns have higher level of ground-water infiltration. Paddy fields which have low level of infiltration capacity is potential to cause flood, especially at the time when rainwater exceeded the height of paddy fields' embankments. The whole area of paddy fields in Lowokwaru Subdistrict are are technically irrigated with planting intensity of 2.09, which means that most farmers plant rice-crops twice a year and leave the field fallow at the third season. Paddy fields' buffering capacity or its capability to retain rain and surface run-off water per hectare is affected by the margin between heights of embankment and water-flooding. As the water-flooding height of paddy fields are similar in all villages, then the difference in buffering capacity of each village mostly inlfuenced by the difference of height of embankments. Daily buffering capacity for each hectare of paddy field in Lowokwaru Subdistrict in each category is shown in Figure 2.

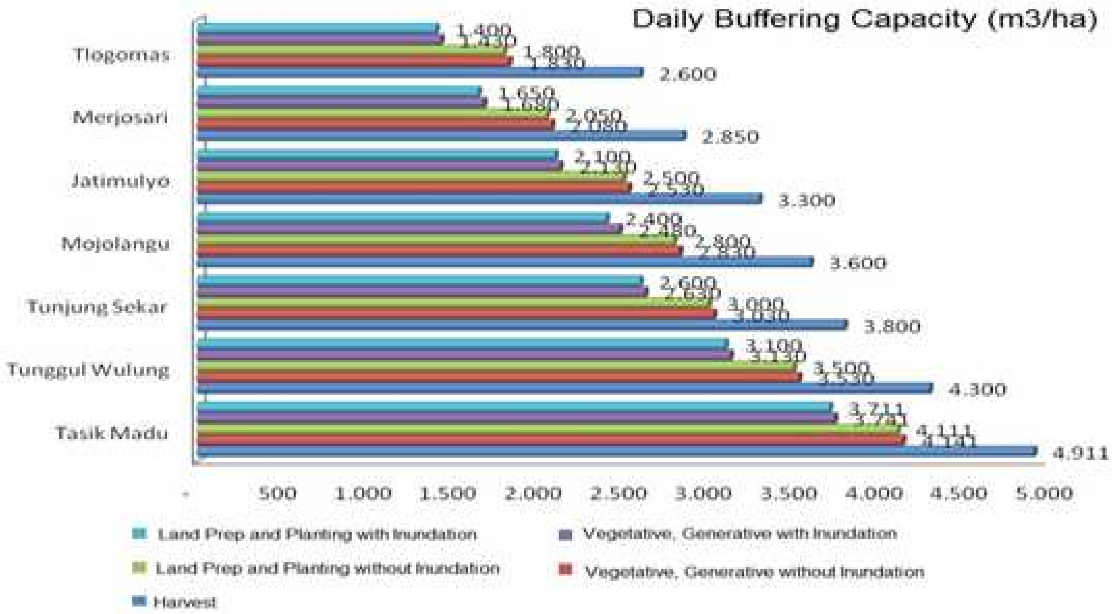


Figure 2. Daily buffering capacity per hectare of paddy field in Lowokwaru subdistrict (m^3/ha)

Compared to other villages, paddy field in Tlogomas village acquired the smallest buffering capacity which is due to the lowest average of height embankments. The OTTG category acquired the smallest buffering capacity compare to other categories which due to the none-existence of plant canopy to retain additional amount of rainwater. In this category rice-plant have not been planted or in early phase of growth. the interception capacity at this category is equal to zero. The lowest buffering capacity in Lowokwaru Subdistrict is bigger when caompare to the average of buffering capacity in Citarum Watershed in West Java, which is 940 m^3/ha (Watung et al., 2003). Conditions of paddy field in Citarum watershed are a mix between flat and gradual field with lower embankments, which highly contributes to that number (Onishi et al., 2004). The average of daily buffering capacity per hectare is the volume rain- and surface run-off water that can be stored by one hectare of paddy field in a single day at the time when rain occurs. Average of daily buffering capacity per hectare of paddy field in one planting season is calculated by multiplying daily buffering capacity of each category with respective water-flooding duration, then divided by the duration of paddy planting per season. Table 3 shows the example of such calculation for Tasik Madu village.

Table 3. Average of daily buffering capacity for paddy field in Tasik Madu village (m^3/ha)

Category	Inundation Period (days)	Daily Buffering Capacity (m^3/ha)	Average of Daily Buffering Capacity per category in Single Planting Season (m^3/ha)
A	B	C	D = B/124 * C
OTTTG	10	4111	331.53
OTTG	16	3711	478.84
VGTG	37	4141	1235.62
VGG	53	3741	1598.98
Harvest	8	4911	316.84
TOTAL	124		3961,81

Using the same method of computation, average of daily buffering capacity per hectare of paddy field for single planting season in other village can be seen in Table 4, which also shows daily buffering capacity of paddy field in Lowokwaru Subdistrict (total of 241 hectares). In total daily buffering capacity of paddy field in Lowokwaru Subdistrict is about 823,156.36 m^3 which is on par with a dam, measuring 4.12 hectares with 20 meter deep. An advantage of paddy fields compare to other water reservoirs in urban area is the none-existence of maintenance expenses bear by to Local Government because the expenses has been paid by farmers.

Table 4. Daily buffering capacity of paddy field in Lowokwaru subdistrict.

Village	Total area of Paddy Field (ha)	Daily Buffering Capacity per hectare (m^3/ha)	Daily Buffering Capacity of Paddy Field (m^3)
Tasik Madu	131	3961.81	519011.20
Tunggul Wulung	36	3350.81	120629.03
Tunjung Sekar	32	2850.81	91225.81
Mojolangu	12	2672.18	32066.13
Jatimulyo	11	2350.81	25858.87
Merjosari	12	1900.81	22809.68
Tlogomas	7	1650.81	11555.65
Average		2676.86	
Total	241		823156.36

Buffering capacity of rainwater and surface runoff

The buffering capacity function of paddy fields is extremely significant when rain occurs, as it stores rain- and surface run-off water. The amount of rainwater stored by paddy fields before flowing downstream is highly depended on the volume of precipitation in that area. Data of Climate concerning rain in City of Malang in 10 years are presented on Table 5. Precipitation is a quantity of rainwater acquired on a flat area that does not evaporate, does not infiltrate, and neither does flow. A 1-mm precipitation translates as the acquirement of rainwater within one milimeter deep in one meter square of flat area which equals to 10,000 liter or 10 m^3 rainwater per hectare of flat area. From 2004 until 2013, the City of Malang experienced an average of daily precipitation ranging from 6.54 to 11.95 mm each day, for which consideres this city as low rate of precipitation area (according to classification set by Indonesian Meterology and Geophysic Agency).

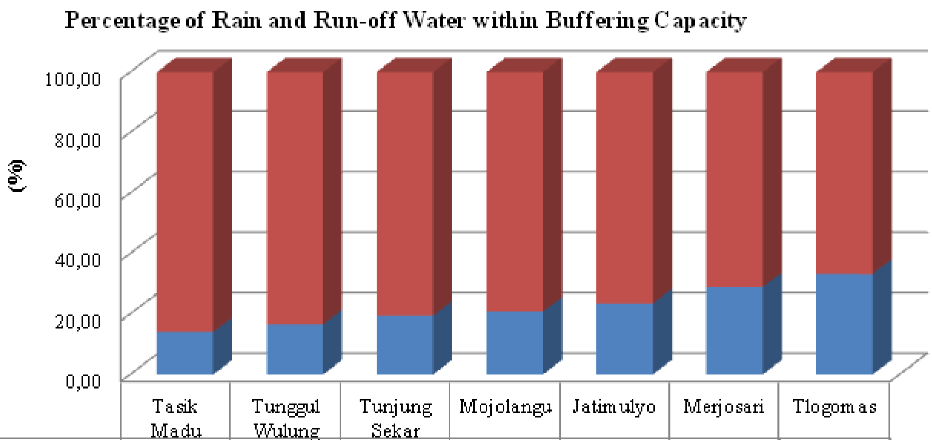
Table 5. Monthly Rain in City of Malang During a Period of 2004 – 2013

Month	Precipi-tation* (mm)	Maximum Rain* (mm)	Days of Rain * (day)	Daily precipitation** (mm/day)	Precipitation Intensity** (mm/hour)
January	207.10	39.50	22	9.41	71.79
February	226.80	39.36	20	11.34	71.54
March	219.90	54.28	20	10.83	98.65
April	174.90	32.59	16	10.86	59.23
May	114.30	28.28	12	9.94	51.40
June	42.60	21.36	6	7.22	38.81
July	24.40	8.00	3	7.39	14.54
August	21.21	9.01	3	8.84	16.38
September	24.20	8.89	3	7.51	16.16
October	59.60	17.57	9	6.54	31.93
November	166.80	48.78	15	10.83	88.66
December	**262.90**	**57.42**	**22**	**11.95**	**104.36**

Source : BPS City of Malang

Notes : * Monthly average; ** Secondary data analysis (using formula of precipitation/Days of Rain); *** Secondary data analysis (using formula of Mononobe for duration of rain for 5 minutes).

With such climate, paddy field in City of Malang is proficient to accommodate rainwater in research locations as their daily buffering capacity are greater than the city's daily precipitation. December as the month with highest average level of daily precipitation of 11.95 mm which is equivalent to 119.5 m^3/ha of rainwater acquired. Paddy fields with average daily buffering capacity of 2,676.86 per hectare is highly capable of storing of rainwater that falls on its maximum quantity. Irrigated paddy field in research locations can function as good drainage channels in urban area during rainy season to curb the flow of rainwater hence minimizing the risk of floods or inundation downstream. Precipitation intensity is one climate parameter that should be closely observed as flood, inundation, and landslide mitigation efforts. Precipitation intensity presented at the above table using Mononobe formulation for 5 minutes rain duration. Referring to precipitation intensity classification defined by Arsyad (1989), precipitation intensity in the City of Malang is divided into four classes, which are : (1) very high (>75 mm/hour) in March, November, and December; (2) high (51 – 75 mm/hour) in January, February, April, and May; (3) moderate high (26 – 50 mm/hour) in June and October; and (4) mediocre (11 – 25 mm/hour) in July, August, and September. Precipitation intensity defines as the depth of rainwater per time unit (Suripin, 2003). Precipitation intensity represents the volume of rainwater in a short-period of time to describe precipitation per hour (Agustianto, 2014). At an occurance of high precipitation intensity, paddy fields in Tlogomas village, inwhich buffering capacity is the lowest, will be fulled by rainwater in 1 hour and 44 minutes times, as paddy fields in Tasik Madu village with highest buffering capacity, will be fulled in 3 hour and 57 minutes times, with assumption that there is no water flowing in or out of the paddy field. At an occurance of rain, paddy fields perform two water-retaining tasks which are rainwater (vertical flow) and surface run-off water (horizontal flow). Thus with the existence of horizontal inflow, the duration paddy field to be fulled will be shorter than aforementioned calculation. A Surface run-off is defined as parts of precipitation that flows on the surface travelling to river, lake, and ocean (Asdak, 1995). With assumption that rainwater will fill paddy field first before surface run-off. The percentage of rain- and surface run-off water is calculated based on highest monthly precipitation (December), which is 57.42 mm. The average percentage of rain- and surface run-off water per hectare paddy fields is shown in Figure 3.



	Tasik Madu	Tunggul Wulung	Tunjung Sekar	Mojolangu	Jatimulyo	Merjosari	Tlogomas
Surface Run-off Water	85,93	83,42	80,58	79,23	76,53	71,05	66,69
Rain Water	14,07	16,58	19,42	20,77	23,47	28,95	33,31

Figure. Percentage of rainwater and surface run-off within paddy fields buffering capacity based on highest monthly precipitation

The percentage of precipitation harbored in paddy field is rather small compared to surface run-off water harbored. The amount of surface run-off water is determined by surface run-off coefficient (percentage of precipitation that turns into surface run-off water) for many different type of land utilization. Surface run-off coefficient is affected by numerous factors, such as soil type, slope degree, precipitation magnitude, precipitation intensity, and vegetation type (Chow, 1964). Surface run-off coefficient based on various type of land use: (1) land with buildings (industrial area) will arise surface run-off water of around 50 – 90% of precipitation depends on the area's density; (2) city center will develop of around 70 – 95% surface run-off water; (3) center of rural area will develop of around 50 – 70% surface run-off water; (4) road will develop of about 70 – 95% surface run-off water depends on the quality of road; and (5) under developed areas such as bushes and garden will arise relatively small amount of surface run-off water of around 10 – 13%. Based on the observation on land use at research location, paddy fields are located in (1) wide open areas (Tasik Madu, Tunggul Wulung, Tunjung Sekar, and Merjosari); and (2) in limited area and that situated among buildings (Tlogomas, Mojolangi dan Jatimulyo). Referring to Chow's study, surface run-off water coefficient in Lowokwaru Subdistrictis is calculated to be 70%, with justification that some part of Lowokwaru subdistricts are shaped as city centre, as other part are also shaped with paddy field, garden, and country roads. The ilustration of surface run-off water volume based on maximum monthly precipitation is shown in Figure 4.

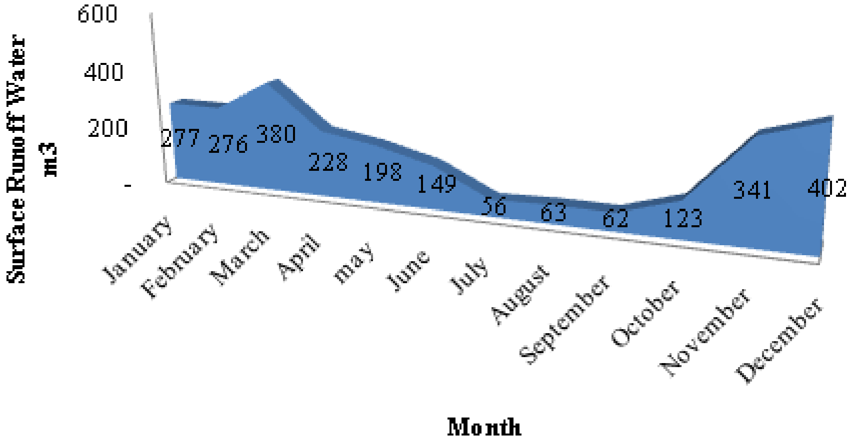


Figure 4. The Amount of surface run-off based on maximum precipitation

A Surface run-off happens when precipitation intensity surpasses its soil infiltration capacity. The law of gravity states that water will flow from higher to lower areas, thus befalls to surface run-off water. While travelling to lower areas, surface run-off water will first fill concave areas, like paddy field, before continues to flow down to rivers or lower areas. Surface run-off water is assumed to be produced by built lands surrounded paddy fields. Using the largest surface run-off water calculated, 402 m^3, paddy fields in Lowokwaru Subdistrict can store surface run-off water produced by surrounding built areas as calculated in the following Table 6.

Table 6. Buffering capacity of paddy field to accommodate surface runoff based on the peak of surface runoff

Village	Remaining Buffering Capacity of Paddy Field m^3/ha	Acreage of Built Areas as Source of Surface Runoff	
		per hectare	Total Village (ha)
Tasik Madu	3404.51	8.5	1109.43
Tunggul Wulung	2795.29	7.0	222.51
Tunjung Sekar	2297.08	5.7	205.71
Mojolangu	2117.30	5.3	36.87
Jatimulyo	1799.01	4.5	53.70
Merjosari	1350.56	3.4	40.32
Tlogomas	1100.99	2.7	30.13
Total	14864.72		1698.66

The remaining buffering capacity of paddy field is a portion of paddy fields' buffering capacity that is not yet filled with rainwater, and is expected to be filled by surface run-off water. The table above shows that one hectare of paddy field in Tasik Madu village can store surface run-off water which is produced by 8.5 hectare of built-areas that surrounds or upper/higher of the paddy fields. For whole 131-hectare of paddy field in Tasik Madu village, it is calculated to be able to store surface run-off water from 1,109.43 ha of built-areas. Furthemore the total acreage of paddy field in Lowokwaru Subdistrict can store surface run-off water that produced by 1,698.66 ha of built-areas. As an attempt to increase potential buffering capacity of paddy field so it can store more amount of surface run-off water is by elevating the height of embankments. As a simulation, if embankment height is raised to 0.41 m (as high as paddy field height in Tasik Madu village) for the entire area of Lowokwaru Subdistrict, then the whole paddy field will be able to water as much as 954,796.21 m^3 that produced by 2,375.11 hectares of surrounding built-areas. That upgrades the buffering capacity, with the new capability to store water from about additional 676.45 hectares of surrounding built-areas that produces of about 131,639.85 surface run-off water.

Potential disaster due to paddy field conversion

At recent flood has become a hydro meteorology disaster that increasingly escalates in frequency, intensity and distribution. The flood frequency and intensity is affected by global climate change (precipitation), land utilization and coverage change, riverbank utilization change (as habitation and industrial area), river damage, etc. (Mirza, 2002; Jiang et al., 2005; Nugroho, 2008; Zhang et al., 2014; Zhang et al., 2016; Zope, et al., 2016). Land-use change (land conversion) has altered the characteristic of land surface to be open and solid that cause rainwater to directly hit the soil particles. The strength of precipitation that hits uncovered land-surface will destroy soil's aggregate, increase runoff, as well as transports soil particle and soil organic material (land erosion) (Widianto et al., 2004; Cebecauer and Hofierka, 2008; Chen, et al., 2016). In general, land conversion has an impact to hydrology cycle, both underground water and surface water, including the change in water quality and water flow (Meyer dan Turner II, 1992; Saghafian et al., 2008; Fox et al., 2012; Kulkarni et al., 2014). Eventhough paddy field offers multi-benefits to environmental preservation, but its existence at sloping areas are unfortunately prone to landslide. Although landslides normally arise in areas that slants over 3%. Paddy fields at lower area (flat field) has very low risk of landslide. Water-flooding and field-puddling will cause soil aggregates to be destroyed into loose granules and be easily eroded (Saroch and Thakur, 1991; Kirchhof et al., 2000; Kukal and Sidhu, 2004; Mohanty, et al., 2004; Slamet et al., 2013). Precipitations as well as its intensity and distribution contribute to the potential dispersion of soil particles, the amount and speed of surface run-off water, the degradationof soil, and landslide (Barus, 1999; Fang et al., 2012). Precipitation will instigate erosion when the intensity is high, and the duration is long (Utomo, 1989; Xu et al., 2015). A Surface run-off will occur when the precipitation intensity exceeds the infiltration capacity, causing excess water, that firstly accumulates at surface reserves. When the excess water is beyond the capacity of these reserves, then the water then will become a surface run-off. The volume of rainwater becoming surface run-off depends on the ongoing precipitation intensity. The higher the intensity, the larger the surface run-off volume will be (Wei et al., 2007). The surface run-off characters, volume, speed, and fluctuation, are factors for its ability to cause an erosion and flood (Wessels et al., 2007). If the entire 241 ha of paddy fields in Lowokwaru Subdistrict converted to built-areas, such as housing or office complexes, the it will decrease the soil capacity to infiltrate rainwater, thus increases the water volume of surface run-off. Furthermore, land conversion will raise the surface run-off coefficient for the areas. The following Table 7 shows the exchalating volume of monthly surface run-off water when surfaces run-off coefficient advances to 80% and 90% compared to the initial run-off coefficient of 70%.

Table 7. The volume of surface runoff water based on different surface runoff coefficient (m^3/ha)

Month	**Surface Runoff Coefficient**		
	70%	**80%**	**90%**
January	277	316	356
February	276	315	354
March	380	434	489
April	228	261	293
May	198	226	255
June	149	171	192
July	56	64	72
August	63	72	81
September	62	71	80
October	123	141	158
November	341	390	439
December	402	459	517

Not only does a total paddy field conversion in Lowokwaru Subdistrict abolish the buffering capacity of paddy field (to zero), it also produces surface run-off water as much as 960,062 m^3 and 1,080,070 m^3 (consecutively at 80% and 90% surface run-off coefficient of) in December when precipitation hits its peak. Whereas in July when precipitation reaches its lowest, the area of Lowokwaru Subdistrict produces surface run-off water of 133,760 m^3 and 150,480 m^3. As an endeavour to anticipate the risk of flood, the Government of City of Malang have to reproduce more coveage vegetation that are capable of enhancing rainwater infiltration into the ground, repair and upgrade the capacity of drainage, and build run-off reservoir (Sieker dan Klein, 1998; Furumai et al., 2005; Fletcher et al., 2011; Hutchinson et al., 2011). To effectively and efficiently replace the water storing function of paddy field, those water reservoir should be placed dispersedly to cover more areas. To accumulate 1,080,070 m^3 of surface run-off water, requires of about ten reservoirs, measuring 2.700 m^2 with 5 meter deep) that are placed in strategic location to accommodate rainwater runoff (Ladson et al., 2007; Ashbolt et al., 2012; Locatelli, et al., 2015).

Conclusion

The result of the research on ecological services of paddy field as water reservoir in Lowokwaru Subdistrict showed that paddy fields can retain rainwater and surface run-off water when rain occurs. The volume of rainwater and surface run-off water accommulated by paddy field is represented by the value of its buffering capacity. In research location, the buffering capacity is calculated daily, because farmers implements intermitten water-flooding system. Based on factors that are affecting to the value of buffering capacity, which are water-flooding height, variation of plant canopy and soil conditions, there are five different categories of buffering capacity in one planting season, namely Harvest, VGTG, OTTTG, VGG, and OTTG. The average daily value of buffering capacity is obtained by multiplying number of days in a category with the value of respective buffering capacity in the same category, then divided by duration of planting season (124 days). At the occurance of rain, the majority of buffering capacity will taken up by surface run-off water (66.69 – 85.93 %), as the rainwater will only taken up small part of buffering capacity (14.07 – 33.31 %). The value of buffering capacity is determined by the paddy fields' embankment height; therefore, village that has the highest embankment height, holds the largest buffering capacity. By elevating embankment height, a larger buffering capacity of paddy field will be achieved. Paddy field conversion that totally destroys the existence of paddy field will not only abolish the existing buffering capacity but also generate the increasing volume of water that comes from surface run-off, which amplify the potential occurance and risks of floods and inundation. To anticipate this risk, the City of Malang, should put water infrastucture in place, such as drainage channels and water reservoirs. The running water of surface runoff will be accomodated by drainage systems, as water reservoirs (lake or dam) will be the destination of water from surface runoff which will hold the water temporarily or permanently. A financial advantage gained by the City of Malang by maintaining the existence of paddy field is the absence of maintenance and repairement expenses. These expenses are called as farming expences which already been paid for by farmers personally.

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