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THE POTENTIAL FOR RAINWATER HARVESTING IN MAKASSAR COASTAL AREA, SOUTH SULAWESI, INDONESIA

M. Yahya
Department of Architecture, Faculty of Engineering,
Hasanuddin University of Makassar South Sulawesi, Indonesia

Ananto Yudono
Department of Regional and City Planning, Faculty of Engineering,
Hasanuddin University of Makassar South Sulawesi, Indonesia

Farouk Maricar
Department of Civil, Faculty of Engineering,
Hasanuddin University of Makassar South Sulawesi, Indonesia

Arifuddin Akil
Department of Regional and City Planning, Faculty of Engineering,
Hasanuddin University of Makassar South Sulawesi, Indonesia

ABSTRACT

Land Development in a region reflects its hydro-geological space functions. The population and infrastructure growth in Makassar City has had an impact on land needs for various activities and the availability of water sources. The concept of Low Impact development (LID) is one of the approaches to overcome the problem of raw water scarcity in urban areas. This research was aimed at studying the potential for rainwater harvesting in the coastal city of Makassar by analyzing land cover changes spatially, rainfall changes and impacts of surface runoff on the land with the model of Soil and Water Assessment Tool (SWAT). The analysis results show that there was an increase of 3.92% in the land use for settlement in the Tallo River Watershed in the period of 2002-2012. On the other hand, there was a decrease of 1.19% in the land use for rice fields and shrub areas. The increase in land cover played a role in increasing surface runoff by 37.49%. In 2002 the runoff was 78,120 mm. In 2007 it increased to be 124,987. It can be assumed that land characteristics, rainfall and surface runoff become potential variables for developing sustainable conservation of rainwater resources.

Key words: Water Conservation, Land Cover, Surface Runoff.

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1. INTRODUCTION

One general problem faced by big cities in Indonesia is high population growth, which is contributed by natural population growth and urbanization. Rapid population growth and development activities in various sectors in urban areas have led to an increase in land demands, which is due to an increase in space needs [1]. This phenomenon is unavoidable and has occurred rapidly in cities which have narrow areas but play a significant role as growth centers. Urban development has significantly changed environmental and ecosystem conditions [2].

Land cover and use are influenced by human activities that play an important role in social, economic, and political dynamics which lead to growth or changes [3]. Rapid growth and development have created problems in Makassar City, one of which is the scarcity of clean water resources. This condition is triggered by high population growth, which leads to high-level clean water consumption. In addition, rapid urbanization and industrialization in the city have a negative impact on water resources in general and groundwater in specific.

The need for raw water in urban areas can be fulfilled by making use of rainwater. A developmental approach based on Low Impact Development (LID) is one of the ways to control rainwater runoff in such a way that it can be used as raw water source and that it can infiltrate the soil and evaporate rapidly so that flooding and drought can be minimalized. This concept applies the management of rainwater runoff which respects conservation aspects. LID is a strategy for managing rainwater by protecting and developing natural hydrologic functions of an area so that the purposes of natural resource conservation can be achieved and the required environmental regulations can be met. [4].

Land Development in a region reflects its hydro-geological functions. Widespread land conversion will widen impervious land surface, which leads to reduced infiltration, groundwater decline, and increasing surface runoff. These changes will in turn influence the system of water balance. Therefore, hydro-geological functions will shift over time and space [5].

Rainwater Harvesting (RWH) provides a sustainable solution for the problems of clean water scarcity and urban flooding across the world. RWH has been practiced in some rural areas, but in urban areas it has been practiced very little. Hydrological modeling with geospatial techniques supported by hydrological modeling using HRE-HMS can be used to simulate the process of managing surface runoff that can decrease water puddle [6].

Continuous water scarcity and global climate change necessitate more efficient water conservation systems. One of the most rewarding systems is Rainwater Harvesting (RWH). However, for the management of rainwater on a large scale, the assessment of rainwater harvesting potential and the selection of suitable locations for the RWH structures is very challenging [7].

There have not been any studies on RWH in urban coastal areas. Makassar City falls into the category of coastal city. These facts underlay the conduct of the current study. An analysis was required to determine land cover changes spatially, rainfall changes and the impact of surface runoff on land use. The analysis results were used to assess the potential for rainwater harvesting in Makassar City.

2. MATERIALS & METHODS

The research method used was the one using Soil and Water Assessment Tool (SWAT) with Geographic Information Systems (GIS), which was supported by several data such as watershed border maps, ASTER DEM 30m data, soil types data, river networks data, climate data and land cover data. The research was carried out by simulating a model which could show the characteristics of watershed hydrology by taking into account the aspects of climate, soil, slope, and land cover. The SWAT model simulation covered three steps, namely (1) input parameters, (2) model running processes, and (3) defining of the model simulation output, which was surface runoff.

The development of Geographic Information System (GIS) and remote sensing in the forms of data collection, data processing and data presentation devices, as well as analysis knowledge is really useful for identifying land cover in a certain region (Zulkarnain, *et al.*, 2015). The approach of GIS is useful because it provides a working framework for collecting, storing, analyzing, changing and presenting spatial and non-spatial data for certain purposes. Emerging geospatial technologies such as remote sensing and GIS have become effective tools to determine a zone potential for rainwater harvesting (RWH), to determine a location suitable for RWH structures and to play an important role in water resources planning and management [9].

Land cover changes result from activities which change land uses for commercial or industrial purposes. Various humans' activities to fulfill their needs rely mostly on land or are carried out on land. Land use activities that change the landscape of a watershed frequently influence water yield. Land cover changes influence water availability [10].

Surface runoff is water from rain that flows over the land to rivers, lakes and seas. Surface runoff occurs when the amount of rainwater exceeds the infiltration rate. Surface runoff is the main hydrological factor causing flooding. The surface runoff whose volume is high and which occurs continuously may cause erosion and transport soil particles and deposit them in water bodies, such as rivers, lakes, and reservoirs. The more sediment is deposited by surface runoff in a watershed, the unhealthier the watershed is [11].

The research location was determined by drawing a line along the borders of the Tallo River Watershed that intersect with the administration borders of Makassar City. The data on land cover in the Tallo River Watershed in 2002, 2007 and 2012 were obtained through image interpretation. Visual Delineation Method was used to determine land cover categories based on the patterns and characteristics, namely hues, colors and texture on the obtained image as can be seen in figure 1.

Figure 1. Map of the Study Area: the Tallo River Watershed in Makassar City

2.1. Rainfall

Rain is a main input of the hydrological cycle in a watershed. Rainfall in a watershed will flow into rivers. Rivers become a natural system collecting surface runoff. The characteristics of rainfall in a region need to be analyzed to determine water availability and possible problems and disasters related to water resources. The knowledge about the characteristics of rainfall in a region related to wet months, humid months and dry months will be useful for the hydrological management in the region. Specifically the knowledge becomes the base for making use of rainwater as well as possible and minimalizing its negative impacts (Arham, *et al*., 2015). The intensity of rainfall can be seen in Table 1.

Table 1 Classification of Rainfall

Annual Rainfall (mm/year)	Description
>4000	Very high
3500 - 4000	High
3000 - 3500	Moderate
2500 - 3000	Low
<2500	Very low

2.2. Infiltration

The amount of water on the ground surface that enters the soil is known as the infiltration rate. A high rate of infiltration will not only increase the amount of groundwater which is important for plant growth, but also decrease erosion and flooding caused by surface runoff.

The infiltration capacity will determine the amount of rainwater that infiltrates the ground and the amount of surface runoff [13] . Rainwater infiltration is usually followed by water puddle on the ground surface. Usually the amount of water that infiltrates the ground in one day is just several centimeters and rarely makes the underground saturated. When it stops raining, the remaining gravity water keeps flowing down while it is being absorbed into capillary pore space [14].

Table 2 Classification of Land Uses

Land Use	Infiltration
Forests	High
Plantations / Gardens	Rather High
Fields	Moderate
Rice Fields	Rather Low
Settlement Areas / Disturbed Lands	Low

3. RESULTS AND DISCUSSION

3.1. Land Cover Analysis

The analysis results obtained were three kinds of data on land cover in the periodical years of 2002, 2007 and 2012. The data were used as a base to see the increase or decrease in surface water flow, which in turn was used to determine the amount of surface runoff. The data on surface runoff became the base for determining a location suitable for rainwater harvesting.

The data on land use in 2002, 2007 and 2012 were analyzed. The analysis results show that there were several land cover changes as shown in table 3.

Table 3 Figures Related to Land Cover Changes in 2002, 2007 and 2012

No	Land Cover	Area (ha)			Change (ha)	Change (%)
		2002	2007	2012		
1	Secondary Mangrove Forests	315	296	260	-55	-0.15
2	Settlement Areas	4,159	4,235	4,921	1,388	3.92
3	Dryland Farming	2,923	2,871	2,831	-92	-0.26
4	Rice Fields	20,826	20,764	20,402	-424	-1.19
5	Shrubs	5,151	4,756	4,745	-406	-1.15
6	Shrub Swamps	41	41	49	8	0.02
7	Fishponds	1,356	1,242	1,126	-250	-0.71
8	Water Bodies	651	660	482	-169	-0.48

The above table shows a big increase of 1,388 ha (3.92%) in land cover from 2002 to 2012 in settlement areas. This was due to regional growth, which was triggered by population growth and an increase in basic human needs, i.e. clothing, shelter and food. Efforts to fulfill basic human needs led to land use changes. Such an increase in land cover was due to the need for more space for settlement (Fajeri, D.B *et al.*, 2017).

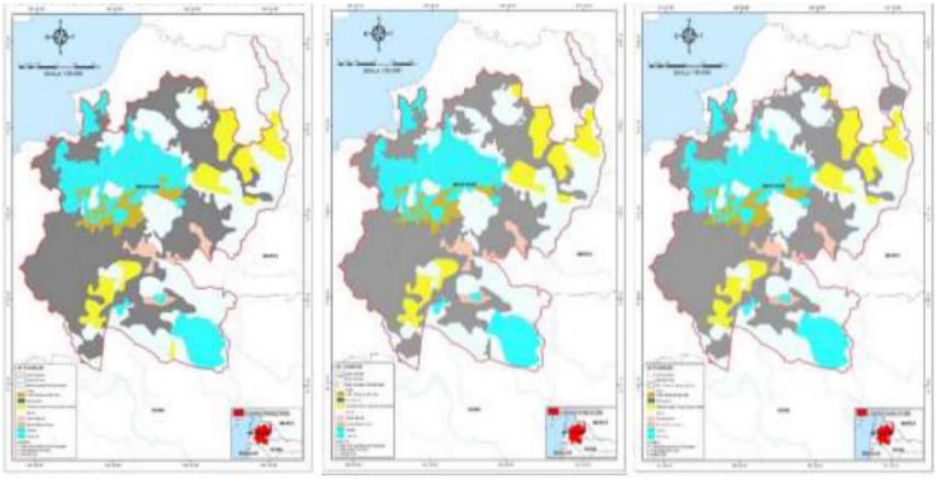

Figure 2 Map of Land Cover in the Tallo River Watershed in Makassar City in 2002, 2007, and 2012

Settlement development which is not accompanied by water conservation efforts will create water resource problems. One direct effect of the problems is flooding. Changes in land characteristics, high intensity of rainfall, and land use changes in a watershed all become important factors in creating a flood [16].

Sustainable water resource management is based on the principle that water sources should be used in accordance with the needed water quantity. Such a management identifies alternative water sources that can be used to fulfill human needs. Rapid population growth especially the one in urban areas has led to an increase in clean water demands. The communities use groundwater besides water supplied by Regional Drinking Water Companies (PDAM). The excessive use of groundwater exacerbated with an increase in land conversion in settlement, office and commercial areas will trigger groundwater depletion. Due to such a condition and the fact that the region has high intensity of rainfall, rainwater harvesting is suitable for Makassar City and has the potential to overcome the problem of water scarcity.

3.2. Rainfall Analysis

In determining the rainfall intensity, the data were analysed with Thiessen Polygon Method. The input data used in the analysis were the global weather measured every year. The measurement results show that the rainfall in the Tallo River Watershed in 2002 was 5.529 mm/year. It had an increase of 7.331 mm/year in 2007 and another increase (relative to the one in 2002) of 6.680 mm/year in 2012.

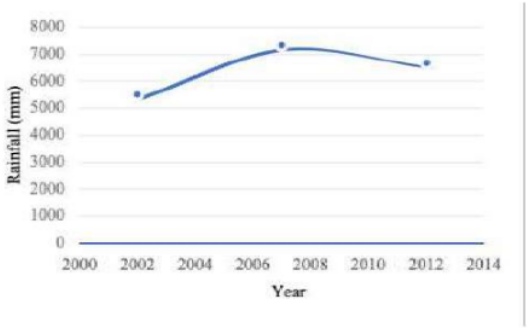

Figure 3. Analysis of the Data on Rainfall in the Tallo River Watershed in Makassar City

The above data show that the rainfall in the region has the potential to be used as a raw water source. In other words, it has the potential to support water conservation in the area. On the other hand, the large number of land conversions will widen impervious ground surface, which in turn will decrease infiltration, decrease groundwater supply and increase the amount of surface runoff. Land cover changes in a region reflect its hydro-geological space functions. The changes will finally influence water balance. Therefore, hydro-geological functions will shift over space and time.

3.3. Surface Runoff Analysis

The figures related to land cover in 2002, 2007 and 2012 in the Tallo River Watershed were obtained from a simulation which used the SWAT model. The data were analysed with the Hydrologic Response Unit (HRU) model, in which the parameters used were land cover data, land type data, slope data and climate data.

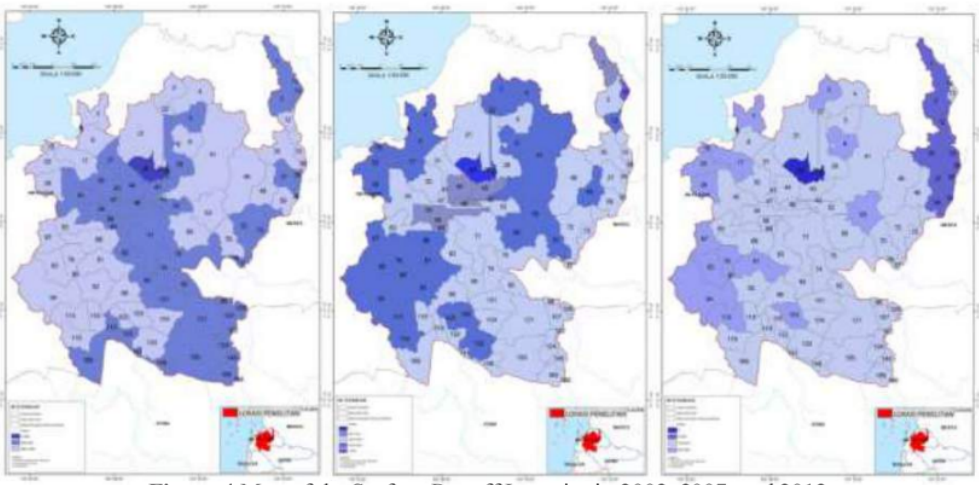

Figure 4 Map of the Surface Runoff Intensity in 2002, 2007, and 2012

The results of the analysis using the SWAT model show that the amount of the surface runoff in the Tallo River Watershed in 2002 was 78.120 mm. It increased in 2007 to be 124.986 mm and decreased in 2012 to be 40.309 mm. The land uses that contributed to the increase in surface runoff were the ones for settlement, rice fields and dryland farming, which had an increase of 44.1%, 45.8% and 35% respectively.

3.4. Hydrological Analysis of Surface Runoff

The simulation of hydrological conditions in the Tallo River Watershed in Makassar City used the SWAT model based on the data on land cover in 2002, 2007 and 2012. Meanwhile, the spatial visualization of the intensity of surface runoff in the Tallo River Watershed in Makassar City can be seen in Figure 7.

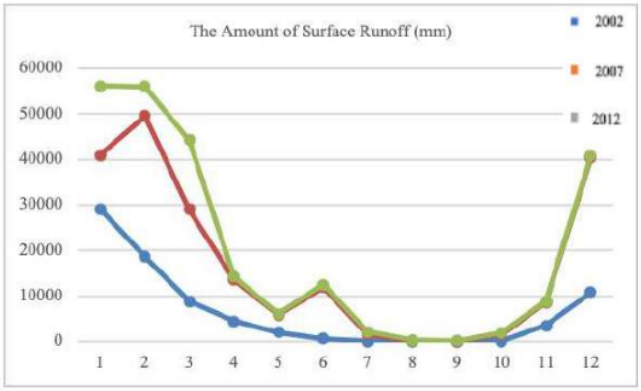

Figure 5 Figures Related to the Monthly Surface Runoff in 2002, 2007 and 2012 in the Tallo River Watershed in Makassar City

4. CONCLUSIONS

The development of Makassar City has led to an increase in urban space needs. This in turn has caused an increase in land cover. The analysis results show that land demands in 2002, 2007 and 2012 played a role in land cover changes in which the space function for rice fields increased by 3.92% and the shrub areas decreased by 1.19%. the amount of rainfall in 2002 was 5,529 mm/year. this increased in 2007 to be 7,331 mm/year and in 2012 to be 6,680 mm/year. the land uses that contributed to the amount of surface runoff were the ones for settlement, rice fields and dryland farming, which increased by 44.1%, 45.8% and 35% respectively. The land use changes resulted in impervious ground surface, which prevented rainwater infiltration. Rainwater directly became surface runoff, which increased the potential for flooding and water puddle. The conditions and characteristics of land, rainfall, and surface runoff in the study area show that the Tallo River Watershed in Makassar City has high potential for optimal rainwater harvesting for sustainable water conservation.

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