Impact of Land Use Changes to Environmental Damage in Bandung Basin

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Abstract: ***A change in the total area of developed lands causes the soil to be impervious. The research aims to: 1. Measure land use changes, 2. Measure the rainfall volume that runs off on the surface of the developed lands; and 3. Analyze efforts of reducing runoff volume in the developed lands in Bandung Basin. The research employed an analysis of the images of the 2010 Landsat 7 Satellite and 2015 Landsat 8 with remote sensing method. The stages of analysis included: Preparation, interpretation, survey, and reporting. The rain intensity was measured with the formula of $R_I = D \times T$, while the rainfall volume was measured with the formula of $V = R \times A$. The analysis results show that the area of developed lands changed from 458,507,000 m^2 to 535,155,000 m^2. The expansion of the developed lands has caused an increase in the runoff volume, from 11,737,779.20 m^3 to 13,699,968.00 m^3. Reducing the runoff volume should be done from every 100 m^2 unit of land. The smallest land units should be able to allow rainfall to infiltrate into an infiltration well with a capacity of 8.96 m^3. The changed area of developed lands has caused an increase in the amount of runoff. To solve this problem, the regional government should create extension programs and make policies regulating development.***

Keywords: Developed lands, impervious, runoff, infiltration wells, policy.

1. Introduction

Area Development

Development is intended to increase the society's ability and potentials to meet their needs and sustain their life. The rapid growth affect the development progress will increase the necessities of life, including the need for land resources. In connection with the characteristics of limited land, the dynamics of activities in urban areas raises the competition between agriculture land changes to be built area (Adibah N, Kahar S, and Sasmito B, 2013:142). Urban population growth in particular has continued to increase due to natural growth and urbanization. Population growth will automatically prompt an increase in the needs for food, housing, energy, and other natural resources in order to cater to human needs (Wiryono,2007). The growth demands the fulfillment of such facilities as housing and social and general facilities. Residential development always requires the utilization of the existing lands, thereby changing the land use from non-housing/yard to housing/settlement and road infrastructure (Putro S & Hayati R, 2007). As the human population increases, the demand for food rises. People must either grow food themselves or purchase it. Most people in the developed world purchase what they need and have more than enough to eat (Enger E.E, Smith B.F.V and Bockarie A.T, 2006). In addition, in urban environment, especially in the trans-urban regions, the changes in land-cover features are quite frequent and substantial (Prakash C.R, Asra M, Venkatesh J and Sreedevi B, 2015). The environment in this regard can be defined as the surroundings in which an entity operates. This includes air, water, land, natural resources, flora, fauna, humans and their interrelation (Sawant V.R, 2013). Urban population growth is hand in hand with urban runoff pollution and damages to the environment. Urban runoff pollution is caused when the runoff, while traveling across the urban environment, acquires contaminants that affect water quality (Waters S, Farrell-Poe K and Wagner K, 2011). Decreased environmental carrying capacity has both direct and indirect impacts on human beings, such as flood and landslide.

The impacts of development are felt by the society to the extent that the environment may become an obstacle in the sustainable fulfillment of a decent life. The sustainability of an environment is marked by its management, in which the environment can provide space, comfort, and safety, and not pose any negative impacts. Achieving sustainable development requires collaboration between different sectors and institutions, as well as the participation of all relevant stakeholders and individuals (Mohsen M, Iqbal Z, Kumar U, Ullah W and Akash O, 2013). Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but in the indefinite future. Sustainability is a process which tells of a development of all aspects of human life affecting sustenance (Sefouhi L, Kalla M and Aouragh L, 2010).

Human beings live in a certain area to meet their needs. In order to meet their needs, human beings have to utilize the land, causing disturbance to the stability and equilibrium of the environment (Iskandar D and Sugandi D, 2015). Recovery and protection of streams in urban areas depend on a comprehensive understanding of how human activities affect stream ecosystems (Konrad P.C, Booth B.D and Burges S.T; 2005). Land cover changes can have four major direct (or first-order) impacts upon the hydrological cycle and water quality; they can cause floods, droughts, and changes in rivers and ground water regimes, and they can affect water quality(Meyer W.B and Turner B.L, 1998). Changes in land use are responsible for an increase in the annual runoff between 3.42% – 4.67%. This study showed that the dynamics of runoff can be predicted by forecasting and simulating future land use (Prasena A and Shrestha P, 2013). Increased needs prompt changes in land use for various activities, housing, and general and social facilities. Changes in land use resulting from the various activities cause environmental imbalance.

Sustainable Development

Development that is not accompanied by efforts of creating a balance in the environment will lead to environmental damage. Declining environmental or ecosystem's quality is increasingly felt and has both direct and indirect impacts on the economic, social, and cultural aspects of life (Sukojo B.M, 2003). Various attempts of sustaining the environment have been made, one of which is creating a sustainable water system. Sustainable water systems often comprise complex combinations of traditional and new system components that mimic natural processes. These green systems aim to protect public health and safety, and restore natural and human landscapes (Scholz M, 2013; Gogate N.G and Rawal P.M, 2013). Without such sustainable water systems, a habitat or an environment is more prone to disasters such as flood and landslide. Floods are the most damaging phenomena that affect the social and economy of the population (Smith K and Ward R, 1998). Urban floods may be caused by high rain intensity. Time of Concentration (ToC) of each rainfall is a determining factor for selecting rainfall intensity for each watershed (Idowu T.O, Edan J.D and Damuya S.T, 2013). After the development of residential and commercial buildings has been completed, increased imperviousness will reduce the time of runoff concentration, so that peak discharges are higher and occur sooner after rainfall starts in basins. The volume of runoff and flood damage potential will greatly increase (Weng Q, 2001). A new promising future development is the incorporation of dynamic feedbacks between changing land use and changing environmental conditions and vice versa. Unfortunately such dynamic feedbacks between the socio-economic and biophysical model components are still not or only partially operational in current models and are therefore the most important challenge for land use and environmental modelers (Veldkamp A and Verburg P.H; 2004). Because the sustainability of life is influenced by environmental sustainability, the environment should be maintained and protected. Collaborative conservation strategies for protecting and managing natural resources help in creating a healthy eco-system. A collaborative approach gives a chance in which conservation issues are targeted collectively by using an adaptive management of whole ecosystems, including human communities (Singh M, Sinha A.K and Singh P, 2014). A new sustainability index is developed as a measure of how exergy efficiency affects sustainable development. Exergy can also identify better than energy the environmental benefits and economics of energy technologies. The results suggest that exergy should be utilized by engineers and scientists, as well as decision and policy makers, involved in green energy and technologies in tandem with other objectives and constraints (Rosena M.A, Dincera I and Kanoglub M, (2008). Conservation is closely related to the socio-economy of the inhabitants. If the land is damaged, the sustainability of the resources will decrease and eventually this will impact on the sustainability of life and development (Klijn F, Kreibich H, De Moel H and Rowsell E.P, 2015; Sugandi D, 2014). Community empowerment needs to be supported by various parties, because it involves sustainable development of the place in which the communities live and gain sustainable benefits from (Sugandi D, 2015).

The above statements show that human beings live in an environment, but if the environment in which they are living continues to experience damages, the sustainability of their life will be negatively affected. In other words, the sustainability of human life is really dependent upon environmental sustainability. Therefore, human beings as a component of the environment should always maintain the equilibrium. Environmental equilibrium requires human beings to utilize the environment wisely.

Land Conservation in Developed Lands

The knowledge about land use and land cover is gaining importance for the study of socio-economic data planning. The land use means the changes occurred on the land due to residential, industrial, institutional etc (Usha, Naveenchandra B, Thukaram M, and Mohandas C, 2015). Land use plan will tend to increase the amount of surface runoff. The upstream watershed has turned into a developed area so that there is no longer sufficient land to be used as retention basin that can reduce the volume of flood flowing to the river (Saud I, 2007). Urban and suburban development is shown to affect flood flows to a significant degree. Improvements of the drainage system may reduce the lag time to one eighth that of the natural channels. This lag-time reduction, combined with an increased storm runoff resulting from impervious surfaces, increases the flood peaks by a factor that ranges from two to nearly eight. The flood-peak increase depends upon the drainage-basin characteristics and the flood recurrence interval (Anderson D.G, 2001).

Development is related to land use changes which in turn are related to population activities that may cause land surface to be impervious, especially such uses as residential, social, and general facilities. The water at first will wet rock vegetation and buildings and then turn into surface runoff (Indriatmiko H.I, 2010). Cities as centers of human activities with the highest population density will be dominated by developed lands (Rushayati S.B, Alikodra H.S, Dahlan E.N and Purnomo H, 2011). The forest is influential on three interrelated factors of the environment, namely climate, land, and water procurement for various areas (Sugandi D, 2014). Flood will affect people's life and activity. Flood is one of the perennial problems in the Philippines, especially in Metro Manila. The inhabitants are affected in many aspects such as livelihood, studies, health and activities. Every time a heavy rain pours in, many activities are delayed, some are stopped others destroyed (Ganiron Jr, 2014).

With the great impacts of flood on the sustainability of life, environmental conservation becomes necessary to support life. Conservation is closely related to the socio-economy of the inhabitants. If the land is damaged, the sustainability of the resources will decrease and eventually this will impact on the sustainability of life and development. To keep the resources sustainable, the roles of the inhabitants supported and empowered by the government are needed in doing the conservation (Sugandi D, 2013). Conservation techniques such as percolation pond, check dam etc., can be recommended for better management of land and water resources for sustainable development of the watershed

(Sindhu D, Shivakumar B.L and Ravikumar A.S, 2013). Resource management, both for agricultural and various other human activities, requires an organization that considers sustainable benefits. The management can be in the forms of monitoring and planning. Agricultural and forest monitoring is a valued instrument needed by public authorities (PA) for determining land uses, planning natural resources management and collecting taxes (Nex F, Delucchi L, Gianelle D, Neteler M, Remondino F and Dalponte M, 2015). Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but in the indefinite future. Sustainability is a process which tells of a development of all aspects of human life affecting sustenance (Sefouhi L, Kalla M, Aouragh L, 2010:15). One of the impacts of environmental damage is the increased surface runoff. Departing from the problems of flood and drought above, the research has formulated the following questions:

1) Analyze change of land use in 2010 -2015 at Bandung basin area with remote sensing image
2) Analyze impact of population growth on land use change in the area of Bandung basin area.
3) Analyze the impact of urban areas against an increase in runoff.

2. Methodology

The research location was Bandung Basin. The basin is the upper stream of Ci Tarum that feeds into the distributaries and drains into the Ci Tarum located on Bandung plains. Bandung Basin covers the regions of Bandung City, Cimahi City, Bandung Regency, Bandung Barat Regency, and some parts of Sumedang Regency. Ci Tarum empties to the plains in Rancaekek and Dayeuhkolot regions. To find about land use changes, Landsat 7 (2010) and Landsat 8 (2015) Satellite Images were used. The research employed the remote sensing method, with the following stages: Preparation, interpretation, field survey, re-interpretation, and reporting. The results of image analysis were buttressed by a survey in the field. The analysis techniques included: (a) cropping, (b) image sharpening, and (c) image classification. In the locations made as the research sample, the volumes of rain water to be infiltrated into the ground were measured from the buildings or developed lands and compared to the total area of the lands.

Meanwhile, flood analysis was done by measuring the flow on the surface of Bandung basin using the following formulas:

Rainfall intensity measurement formula:

$R_I = D \times T$

R_I = Rainfall intensity (mm/hour),
D = Rainfall duration (minute),
T = Rain thickness.

The measurement of rainfall volume was evaluated by using the formula:

$V = R \times A$,
V = Volume (m^3),
R = Rainfall (mm),
A = Area (km^2).

3. Results

1. Land Use Changes

Land use is the factor causing changes in water movement. This is so because some of the rain water falling onto the land surface infiltrates, while some will flow as surface runoff, and a small amount of it will evaporate. This is especially true in the lands that initially functioned to infiltrate water and then were changed into lands with impervious surfaces for uses such as residential areas, roads, and other impervious buildings. Land use changes cause imbalance to the environment. This imbalance cannot be directly observed; however, the impacts are obvious. One of the most felt impacts is the decreasing ability of the land to infiltrate water, causing the rain water to fail to infiltrate and a large amount of it becomes surface runoff. When runoff water accumulates, erosion occurs and the surface runoff carries soils and rock materials to the lower areas. To limit the area of Bandung Basin, the analysis was done to the images of Landsat 7 (2010), and Landsat 8 (2015). The analysis results of images show that there are seven classes of land uses.

Based on the image analyses, it can be observed that there are changes in the total area and classes of land uses. The changes in the total area of land uses are displayed in Table 1.

Table 1: Comparison of the Total Areas of Land Use Classes in 2010 and 2015

No	Land Use Classes	2010	2015	Land Area Change (Km^2)
		Area (Km^2)	Area (Km^2)	
1	Settlement and industries	458,507	535,155	76,648 (expanding)
2	Brushes	121,337	129,272	7,935 (expanding)
3	Plantation	82,681	85,580	2,899 (expanding)
4	Mixed gardens	182,685	182,489	196 (shrinking)
5	Forests	265,927	249,243	16,684 (shrinking)
6	Non-irrigated agricultural lands	282,569	395,448	112,879 (expanding)
7	Rice fields	517,791	334,310	183,481 (shrinking)
	Total Area	1,911,498	1,911,498	1,911,498

The total area of settlement and industries as well as non-irrigated agricultural lands expanded, while the total area of rice fields and forests shrank. The change affects the land surface, causing the area of impervious lands to increase.

2. Built Area

Population in 2010 about 7,267.353 inhabitants and in 2015 approximately 7,673,008 inhabitants. Population in 2010 about 7,267.353 inhabitants and in 2015 approximately 7,673,008 inhabitants. This development menybabkan changes in land use. The rapid population growth demands fulfillment, especially in land use. Land use changes cause changes in the surface soil becomes impermeable, causing increased volume of water flow in the rainy season. The impact of the development of land turned into watertight

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land on flooding. The impact of the floods caused all population activities disrupted.

This development leads to changes in land use. The rapid population growth demands fulfillment, especially in land use. Land use changes cause changes in the surface soil becomes impermeable, causing increased volume of water flow in the rainy season. From the analysis of Landsat 7 (2010) and Landsat 8 (2015) shows the changes in land use, especially changes in the area and undeveloped land. Undeveloped land surface is watertight, so it does not have the ability to absorb rainfall. And undeveloped land analysis results are shown in figure 1.

The built up land develop wa affected by population growth. Population growth demands fulfillment, resulting in changes in land use. Land used to meet needs such as housing, where activities such as trade, industry, public facilities and facilities used untu resident services, such as offices, schools, markets and roads.

3. Runoff Volume

The rain water falling on developed lands will turn into runoff. The runoff flows on the land surface and eventually drains into the river. The flow on the land surface is inhibited by various buildings, such as the sidewalks with poor drainage, so that the runoff is concentrated on the plains. Meanwhile, the runoff

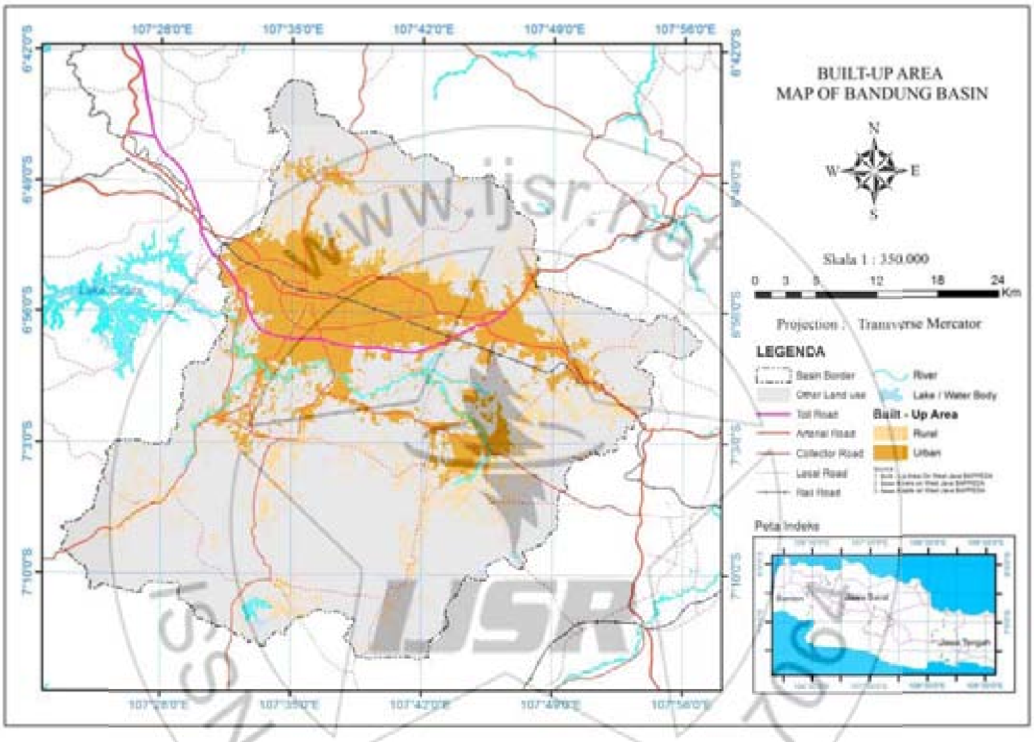

Figure 1: Built Area in 2015

flowing to the river will evaporate. The evaporating surface runoff and river water will get concentrated on the plains and cause floods. The runoff volume is calculated based on the average rainfall from three stations. The lowest rainfall was observed in July, ranging for 35 mm/day and the highest was in December for 336 mm/day in Cileunca, Pangalengan.

The rate of the rainfall should be calculated in the unit of hour; hence, it was divided into 24 hours. Calculated in a 24 hour unit, the rain intensity seems to be small; however, the small rain intensity will get concentrated in the plains into a large volume.

Table 3: Runoff Volumes in Bandung Basin

Month	Rainfall (mm/day)	Developed Land (m^2) 2010	Volume (m^3)	Developed Land (m2) 2015	Volume (m^3)
January	10.9	458507000	4,997,726.30	535155000	5,833,189.50
February	13.8		6,327,396.60		7,385,139.00
March	13.9		6,373,247.30		7,438,654.50
April	12.9		5,914,740.30		6,903,499.50
May	22.1		10,133,004.70		11,826,925.50
June	19		8,711,633.00		10,167,945.00
July	20.5		9,399,393.50		10,970,677.50
August	14.4		6,602,500.80		7,706,232.00
September	25.6		11,737,779.20		13,699,968.00
October	24.9		11,416,824.30		13,325,359.50
November	19.5		8,940,886.50		10,435,522.50
December	17.6		8,069,723.20		9,418,728.00

Runoff will cause monthly flood. Efforts of reducing the increased runoff volume should be made in each smallest land unit. The area of the smallest land unit that is assumed to be quite representative is 100 m^2.

4. Discussion

Land use changes from rice fields, forests, and agricultural areas into settlement, industries, or other uses affect the land surface. Land surface initially functioning to infiltrate rainfall has transformed into impervious layers, so that the rain falling on it fails to infiltrate.

The analysis of Lands at images show that there are seven classes of land use. The land use changes that experience expansion are: settlement and industries, non-irrigated agricultural lands, brushes, plantations, while the lands undergoing shrinking are those intended for such uses as: Mixed gardens (196 km^2), forests (16.68 km^2), and rice fields (183.48 km^2). The land use change for settlement causes surface runoff, while the change for non-irrigated agricultural lands increases erosion, and the flow carries eroded materials because the majority of the lands are open areas. The land use change in brushes causes runoff as well because the lands become impermeable. Meanwhile, changes in plantations cause erosion and runoff because the areas under the tree canopies become exposed. The effects caused by the shrinking areas are as follows: Shrinking forests cause increased runoff; shrinking mixed gardens cause erosion and runoff because the lands become open lands; and shrinking rice fields cause runoff.

Increased runoff due to changes in land use of non-agricultural land into smaller plots such as, residential, office buildings, trade, public facilities and roads. Land is used by built area from 458,507,000 m^2 (458.51 km^2) became widely 535,155,000 m^2 (535.15 km^2). Extensive development of built area increased volume of runoff.

A change from undeveloped to developed lands results in an increase of surface runoff. The total area of developed lands in 2010 was 458,507,000 m^2, with the highest rainfall in September (25.6 mm), so the largest runoff volume was 11,737,779.200 m^3. A land with an area of 535,155,000 m^2 with the same precipitation rate will cause runoff volume of 13,699,968.00 m^3. The runoff of rain water will create a disaster when it gets concentrated. Because runoff flows to lower areas, flood disasters in Bandung Basin are usually found in regions such as Dayeuhkolot, Majalaya, and Rancaekek.

5. Conclusions

The analysis of Landsat 7 (2010) and Landsat 8 (2015) images show land use changes in Bandung Basin. These changes have reduced the infiltration of rainfall, thus increasing surface runoff. The total area of developed lands in 2010 was 458,507,000 m^2, while in 2015 it expanded to 535,155,000 m^2. This expansion has caused an increase in the runoff volume from 11,737,779.200 m^3 in 2010 to 13,699,968.00 m^3 in 2015.

Remote sensing image analysis showed that changes in land use. The results of the analysis of land use is classified into Settlement and industries, Brushes, Plantation, Mixed gardens, Forests, on-Irrigated Rice fields and agricultural lands. Land use change, especially the change of agricultural land into smaller plots.

An increase in the runoff volume has caused an increase in the flood volume in Dayeuhkolot, Majalaya, and Rancaekek regions. To reduce the runoff volume, efforts of infiltrating rainfall into the ground by means of building infiltration wells are needed. The infiltration wells should have the capacity of 8.96 m^3. Hence, the rainfall will not potentially result in surface runoff.

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