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Rainfall-runoff investigation of pine forest plantation in the upstream area of Gajah Mungkur reservoir

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Abstract

Vegetation cover change has a profound influence on the hydrological cycle. A reduction in vegetative cover from forest harvesting generally increases the average surface runoff volume and total water yield for a given area of land. The differences of structure and land cover type are the main baseline in this research to understand the hydrological response of catchment. This research is using two catchment experiments, pine forest and mix-plant forest catchments. Plantation forest with clear cutting system in the mountain area is very sensitive with the changes of runoff and soil erosion. This study investigated the impact of vegetation changes on rainfall-runoff response in different type and periods of Pine forest plantation from their respective forestry treatments. The result shown that in the 7-year old mix-plant forest, direct runoff, peak discharge and runoff coefficient are dramatically increased than that in the 37-year old pine forest. 15 years after planting, direct runoff, peak discharge and runoff coefficient are decreased and reaching to the 37-year old pine forest responses. Implementation of a mix-plant forest method is effective in controlling the hydrological responses of direct runoff, peak discharge and runoff coefficient. The results showed that the magnitude of runoff during different forest treatments depend on interactions among rainfall, forest cover changes and surface disturbance. Forest management practices should consider and attempt to minimize disturbance during each plantation stage to control runoff response.

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Keywords: rainfall;runoff;catchment experiment;pine forest;mix-plant forest

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1. Introduction

Water related disaster is one of the major issues confronting human kind and environment today. The problem arises due to the rapid development from forested area to development area to accommodate population growth. Forest degradation is a serious environmental, social and economic problem. Forest degradation involves a change process that negatively affects the characteristics of a forest such that the value and production of its goods and services decline. This change process is caused by disturbance (although not all disturbance causes degradation), which may vary in extent, severity, quality, origin and frequency. Disturbance may be natural (e.g. that caused by fire, storm or drought), human-induced (e.g. through harvesting, road construction, shifting cultivation, hunting or grazing) or a combination of the two. Many tropical forests of the world are being managed unsustainably, generally due to the intensity of the timber harvest and the lack of adequate techniques to preserve sustainability, that is, to preserve ecosystem structure and function and to ensure the ability of the forest to regenerate populations of desirable tree species. Suryatmojo et al.[1] have synthesized results of catchment experiments, which have clearly demonstrated that reduction in forest covers will increase the amount of stream flow and erosion.

One of the common forms of land use change in humid tropical regions is the clearance of ground vegetation in association with timber harvesting, agricultural cultivation, mining, residential, and recreational development[1,2]. The presence of soil erosion in forests is a prime indicator of forest degradation. Soil erosion can have a major impact on a range of forest services – it reduces water quality, pollutes watersheds with nutrients and sediments, and is an indicator and cause of reduced soil fertility (and potentially, therefore, reduced forest productivity). In an extreme form it can also restrict access to the forest and hinder the extraction of products such as timber[4]. Land surface modification that involves the removal of vegetation cover severely alters near-surface hydrologic processes and accelerates surface erosion[5], potentially resulting in a variety of on- and off-site consequences such as reduced site productivity, degradation of downstream water/habitat quality, channel morphology and water balance[6,7,8,9,10,11].

Watershed as a hydrological system are composed of 3 main component, input is rainfall, process is watershed as water regulator, and output are runoff, sediment and nutrient element. The main elements are soil, land use, land cover, topography, and slope. In some condition with variation of rainfall, pattern and type of land cover, kind of soil, geology, topography and watershed morphometric in together will influence to water flow. When the variation of rainfall, kind of soil, geology, topography and watershed morphometric are the same, the water discharge is influence by pattern and type of it land cover. Catchment characteristic in rainfall response will influence the volume of evapotranspiration, infiltration, percolation, overland flow, soil moisture and river flow. In the Java Island, Indonesia, plantation forest is dominant and managed by a semi-private company, PT PERHUTANI. Forest in the mountain area is planted with Pine (*Pinus merkusii*), while in the lowland area is planted with Jati (*Tectona grandis*). Plantation forest with clear cutting system in the mountain area is very sensitive with the changes of runoff and soil erosion. This study investigated the impact of vegetation changes on direct runoff, peak discharge and runoff coefficient in different type and periods of Pine forest plantation from their respective forestry treatments.

2. Materials and Method

2.1. Study Site

The study area located at Karang Tengah sub-district, Wonogiri District. It is around 75 km southeast of Wonogiri city. It is lies between longitude 111º03’30” - 111º04’55” and latitude 8º01’20” - 8º02’05” with the altitude ranged from 580-1,000 m. Surficial geoglogy of this area is dominated with carbonate rocks non-karst. The average annual precipitation is ranged from 1,922 to 3,489 mm[12,13].

2.2. Experimental Catchment

The pair-catchments method was used in the study which two experimental catchments were established side by side (Fig.1). This research was conducted in two small catchments of Pine forest with different type of vegetation