摘　要

存在於坡面上的植生對於地表水流會造成一些影響，例如：使得地表面粗糙度增加，減低流速，使流體的剪應力消減以及使水流的能量消散，或是減低輸砂效應、增加淤積等等。本文以水力學的角度來分析此類流況的物理現象，考慮坡面上有可能存在木本植物或草本植物，水深有可能高於或不及草本植物的高度，依不同條件分別予以探討。為更接近真實情況，本研究將土壤視為一具滲透性之孔隙介質，考慮土壤呈飽和狀態且水體僅向主流方向移動，因此地表面之流速不為零，相較於許多過去研究使用無滑移邊界條件者，更貼近真實現象。

本研究模擬植生坡面上之薄層流(抑或稱為漫地流)，並假設以層流理論進行分析。水層之控制方程式是以 Navier-Stokes 方程式來描述；植生層與土層之控制方程式則以 Biot 孔彈性介質理論為基礎，依不同的植生狀態加以修正、無因次化和求解。首先，針對整體的流速分佈進行求解，除了有木本植物存在的流況外，皆能求解出流速分佈的閉合解。之後，進一步將水流剪應力分佈、能量率分佈求出、繪圖以及探討。

本論文分析的植生坡面分為兩種，分別為僅種植草本植物的植生坡面以及同時種植草本與木本植物的植生坡面，此兩種植生坡面上之漫地流水深可再分為水深淹過草高與水深不及草高兩類流況進行分析。在水深不及草高的案例中，發現流速隨著孔隙率的增加而增加，而最大剪應力皆位於地表面上，另外，在能量分析的部分則發現坡面上同時種植草本與木本植物的流況下，能量消散率會比僅種植草本植物的流況多出一項由木本植物造成之能量消散。水深淹過草高的流況下，當草之密度越大時，流速剖面中反曲點也愈明顯。在探討剪應力

分佈時，在無種植木本植物的流況中發現:當水層深度與草層厚度相等時，可得到一無因次參數δ_2約等於 9.5，此時，水、草交界面和地表之剪應力相等，且等於最大剪應力，也發現此流況下之流體剪應力分佈可依δ_2與δ_{c2}的關係分為三種類型。而由能量分佈圖，可知最大的能量消散率皆存在於孔隙介質交界面處。

關鍵字：孔隙介質、植生水流、流速分佈、剪應力分佈、能量損失

Abstract

The existence of grasses on the ground increases the surface resistance, and thus decreases the flow velocity and sediment transport rate. Based on the theoretical analysis, vegetated flow on the slope is considered with emergent and submerged vegetation. Herbaceous species, such as grasses, or woody species, such as trees, are planted on the slope separately or simultaneously. In the study, the soil and vegetation layers are assumed to be homogeneous and isotropic porous media. Since the soil ground is considered as pervious and saturated, both surface and subsurface water flow are solved simultaneously. Compared with the no-slip condition at the surface ground used in the past researches, this study is more feasible and close to the natural phenomenon.

The sheet flow or overland flow was simulated by the theory of laminar flow passing over a vegetated slope. The Navier-Stokes equations were employed to govern the flow in water layer, and the Biot's theory of poro-elasticity was applied to delineating the flow in vegetation and soil layers. These equations were firstly simplified, modified and nondimensionalized under different vegetation situations, and then solved analytically. As a result, the velocity distributions with closed form were derived except the case of vegetated slope with woody species. The shear stress distribution and the energy distribution were also analytically derived and discussed for understanding the flow mechanism.

The vegetated slope was divided into two cases--only herbaceous species planted on the slope and both herbaceous species and woody species planted on the slope. Furthermore, the flow mechanism of these two cases with emerged or submerged vegetation was investigated. In the emerged situation, the velocity profiles show that the flow runs faster for less dense vegetation, and the shear stress distribution reveals that the maximum value always occurs at the ground surface. In the vegetation layer, the rate of energy dissipation influenced by woody species is very obvious. When the water depth is higher than grass height, the velocity profiles show that an inflection point appears obviously in the vegetation layer for the denser vegetation with constant water depth. When the shear stress distribution was discussed for the submerged case without woods, a crucial parameter was found. When the dimensionless parameter δ_2 equals to 9.5 approximately with the ratio of the water depth to the grass height equal to unity, the shear stresses at the interface of water/grass layers and at the ground surface are equal and reach to a maximum. The shear stress profiles can be classified into three different types according to the parameter δ_2. From the distribution of energy rate, it is also shown that the major energy dissipation rate exists near the interface of porous medium layers.

Keyword: porous medium, vegetated flow, velocity distribution, shear stress distribution, energy loss.