Abstract

In the last few years, a lot of research attention has been paid to flow and vegetation interactions around dense vegetation patches. However, no comprehensive experimental investigation has been carried out so far to study turbulence in and around sparse and emergent vegetation patch. This study is significant since popular crop jute plantations belong to emergent and sparse vegetation family. Turbulent hydrodynamics in sparse and emergent vegetation patch are important since they govern vorticity generation, mixing and transport of mass, momentum and kinetic energy and finally morphodynamic processes in and around the patch without any blockage effect.In this direction, the present study experimentally investigates variation of turbulence characteristics in lateral and streamwise direction interior and around the sparse vegetation patch.

The main objectives of the present work are as follows: (1) to study turbulence characteristics such as three dimensional flow velocities, three dimensional turbulence intensities, Reynolds stresses, and turbulent kinetic energy along the streamwise and lateral directions through the vegetation patch which is located in the middle region of the cross-sectional area of the open channel; (2) to investigate the anisotropy, bursting events, correlation coefficient, energy spectrum, streamlines and strength of the vortex system in and around the sparse vegetation patch; and (3) to study similarity and scaling of turbulence characteristics in the interior and the wake region of the vegetation patch.

An emergent and rigid sparse vegetation patchmade by seventy uniform rigid acrylic cylindrical rods withregular spacing between stems along the flow and transverse directions was fixed in thecentral region of the cross-section of a wide open channel flume. Experiments were conducted in subcriticalflow conditions. Instantaneous velocity measurements were obtained with the acoustic DopplerVelocimetry system. The raw velocity data was post processed using the established filtering techniques. In this study three sets of flow conditions were investigated, namely Re1Ar1, Re1Ar2 and Re2Ar2. This implies that there were two aspect ratio with same Reynolds number and two Reynolds numbers with same aspect ratio.

In this study, large variations of the turbulence intensities, Reynolds shear stress, turbulent kinetic energy and vortical motions are found in and around the vegetation patch. At any cross-section through the interior of the vegetation patch, streamwise velocity decreases with increase in streamwise length and the velocity profiles converge from the log-law to a linear profile with increasing slope. The average velocity is the appropriate scaling parameter for normalizing the streamwise velocity profiles along the centerline of the sparse vegetation patch.Time-averaged lateral and vertical velocities inside the vegetation patch increase with increasing streamwise distance. The turbulence intensities interior of the sparse vegetation patch are more than those of without the vegetation patch. Similar to the trend of streamwise velocity profiles inside the vegetation, turbulence intensities and longitudinal-normal Reynolds shear stress profile decreases with streamwise direction. In the interior of the vegetation patch, shear velocities are proportional to

aspect ratio for a given Reynolds number. Further, shear velocities are proportional to Reynolds number for a given aspect ratio.In the interior of the vegetation patch and downstream of the trailing edge, turbulent kinetic energy profiles are exhibiting irregular fluctuations and the maximum values are occurring in the outer layer. Analysis of flow distribution confirms sparse vegetation patch is inducing a serpentine flow pattern in its vicinity. In the interior of the vegetation patch, streamlines are following a zig-zag fashion at varied degree along the streamwise and lateral directions. The immediate upstream of the leading edge and in the interior of the vegetation patch, vortex motion is clearly visible and the vortices are stretched along the width of the channel with streamwise direction.Wall wake similarity is observed in the damping of velocity profiles immediate downstream of the vegetation patch.The bulk scaling of velocity profiles in the vegetation patch is found to be described by the power law.Finally, this study presents useful information about the turbulent hydrodynamics in emergent and sparsely vegetated open channel flow where the vegetation patch is located symmetrically in the middle of the channel.

Keywords: Emergent and Sparse vegetation; Open channel flow; Turbulence; Anisotropy; Self-preservation; Quadrant Analysis