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Eucalyptus geometry in agroforestry on waterlogged saline soils influences plant and soil traits in North-West India

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ABSTRACT

Impacts of agroforestry comprising wheat and rice crops in combination with *Eucalyptus tereticornis* trees having high transpiration rate were assessed for remediation of waterlogged saline soils. To find out optimum spacing of trees in strip plantation for higher water table draw down, wood production and crop yield, a study was carried on waterlogged fields by planting *E. tereticornis* (clone C-7) in paired rows on ridges (0.5-m height) made along the field boundaries in north-south direction at 1 m × 1 m, 1 m × 2 m and 1 m × 3 m spacing resulting in population of 300, 150 and 100 trees ha^{-1}. The results were also compared with the control (field without tree plantation) and block plantation. During sixth year of growth, *Eucalyptus* attained the maximum growth in 1 m × 3 m spacing followed by 1m × 2m, 1m × 1m; and minimum in block plantation. Due to higher number of trees per unit area, timber dry wood production was 33.5 Mg ha^{-1} in spacing of 1 m × 1 m; 19.1 Mg ha^{-1} in 1 m × 2 m and 13.5 Mg ha^{-1} in 1m × 3 m and sequestered 15.2, 8.9 and 6.4 Mg C ha^{-1}, respectively. Block plantations of *Eucalyptus* generated 141.7 Mg ha^{-1} timber wood biomass and sequestered 66.5 Mg C ha^{-1}. The transpiration rate of *Eucalyptus* in block plantation on an average was 40.0 L day^{-1} $tree^{-1}$ compared to 68.0, 71.5 and 73.8 L day^{-1} $tree^{-1}$ in 1 m × 1 m, 1m × 2 m and 1m × 3 m tree spacing, respectively in strip plantation. The corresponding total amount of water transpired per annum was 1825 mm in block plantation and 745, 391, 269 mm in 1 m × 1 m, 1 m × 2 m and 1m × 3 m tree spacing. Due to high transpiration rate of *Eucalyptus*, water table was lowered by 43.0 cm in 1 m × 1m; 38.5 cm in 1 m × 2 m and 31.5 cm in 1 m × 3 m spacing during the fourth year of plantation than in adjacent fields without plantation. Near the tree lines, grain yields of both wheat and rice were comparatively low. But lowering of water table resulted in improvement in soil properties which produced 1.7 and 1.3 folds higher grain yield of wheat and rice respectively compared to control. The results suggested that in a rotation of six years, 1 m × 1 m spacing for strip plantation of *Eucalyptus* in paired rows on farm acre line was the optimum for achieving higher water table draw down, wood biomass production, carbon sequestration and crop productivity on waterlogged fields.

1. Introduction

Canal irrigation introduced for increasing crop production in arid and semi-arid regions caused rise in the groundwater table leading to the problem of waterlogging and secondary salinization (Chhabra and Thakur, 1998; Singh, 2005). These problems are the result of a multitude of factors, including seepage from unlined canals, inadequate provision of surface and sub-surface drainage, over irrigation and use of poor-quality groundwater for irrigation. Waterlogged saline soils apart from environmental degradation result in poor crop yields reducing yields as high as 80% (Shabala, 2011) and finally in abandoning the land from cultivation. World over one-third of the irrigated area faces the threat of waterlogging and 11% of it is already salinized (FAO, 2012). In India, more than 5.6 M ha is waterlogged (NAAS, 2010). In North-West India where lies the study area, about 200 km long axis of arable land is underlain by saline ground water and forms an inland basin with no natural drainage. Efforts to remediate saline waterlogged land

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by installing sub-surface drainage had limited success particularly in land locked areas because of problems associated with disposal of drainage effluent (Ohlendorf and Santolo, 1994). Under these conditions, biodrainage from plantation of trees like *Eucalyptus*, which have high transpiration rate and go straight thus low shading effects, can be a viable alternative for management of waterlogged saline soils (Jeet-Ram et al., 2007; Kapoor, 2014; Minhas et al., 2015). In waterlogged areas, trees can be successfully grown by ridge or mound planting which in turn improve survival and growth of trees (Arya et al., 2006; Jeet-Ram et al., 2011). Reliance on capability of vegetation to reduce water table has been found promising both in India (Chhabra and Thakur, 1998; Jeet-Ram et al., 2011) and abroad (Bhutta and Choudhary, 2000; Heuperman et al., 2002). Moreover, compared to sub-surface drainage technology, biodrainage is more economical because it requires investment only on initial establishment; thereafter the system provides economic returns by means of fodder, wood or fibre. Restoring degraded ecosystems has an additional advantage of C sequestration (Lal, 2004). Afforestation is definitely expected to sequester C in aboveground, but the impacts of afforestation on soil organic carbon are very diverse ranging from no effect to enrichment or depletion (Fialho and Zinn, 2014; Jeet-Ram et al., 2011; Lima et al., 2006; Madeira et al., 2002; Yu and Jia, 2015). Small changes in the soil organic carbon stock could significantly affect atmospheric carbon dioxide (CO_2) concentrations, therefore; need to be investigated along with carbon locked in biomass (Conant and Paustian, 2002; Parras-Alcántara et al., 2015).

Compared to strip plantation, block plantation effectively lowers down water table and sequester high amount of carbon because of more number of trees per hectare. In developing countries farmers have small land holdings and usually show restraints to spare their lands for sole forestry plantation which

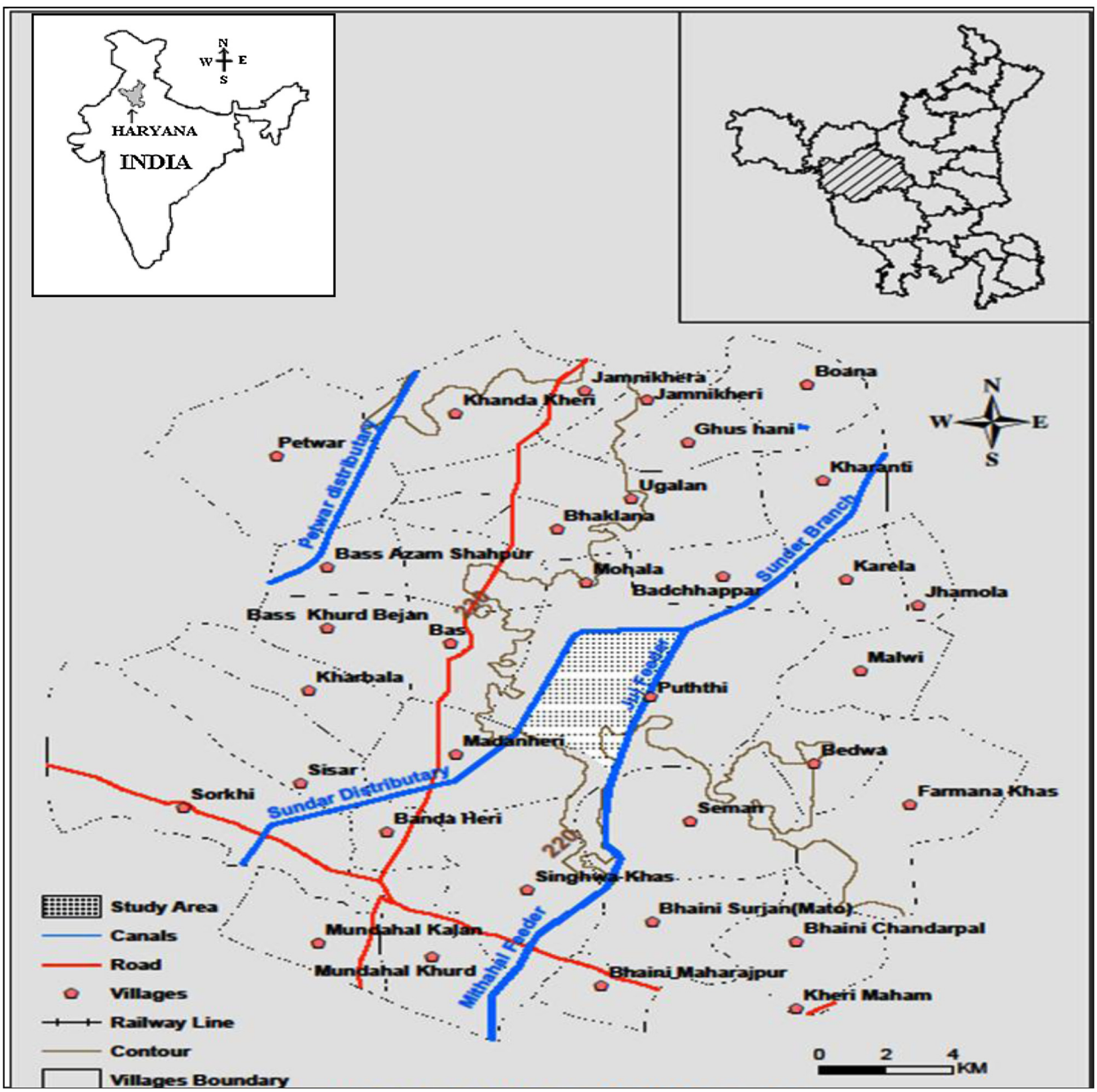

Fig. 1. Location of Research Plot at Puthi.