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India's commitments to increase tree and forest cover

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India plans to increase its forest and tree cover to 33% of its land area.(HT File Photo)

India has committed to reducing greenhouse gas emission intensity under its nationally determined contributions (NDC), made at the United Nations Climate Change Conference in 2015 (COP21). To achieve this goal, India plans to create carbon sinks of 2.5 to 3 billion tonnes of carbon dioxide equivalents by increasing its forest and tree cover to 33% of its land area.

The effort to increase tree cover up to 33% sits within the National Mission for a Green India (GIM), one of eight Missions under the National Action Plan on Climate Change (NAPCC) as well as earlier national forest policy goals. The GIM plans to increase tree cover on five million hectares of designated forest lands and forest on non-forest designated lands and improve tree cover on an additional five million hectares. This effort, if achieved, would ultimately result in three to five million hectares of degraded or marginal agricultural land being converted to forest or agroforestry.

To minimise negative impacts on biodiversity and local pastoral livelihoods, conversion of natural or managed grasslands to forest will also need to be avoided. One of the stated goals of GIM is to improve the hydrological services within the affected landscapes.

Using this as a point of departure, this paper examines the effects of converting cropland to forest cover within the Central India Highlands (CIH) to achieve 33% forest and tree cover within each river basin. It focuses on the impacts on groundwater recharge, essential for sustainable

Rabi season (winter, non-monsoon season) irrigation. The CIH is selected as it contains significant forests and has rapidly increased its agriculture production and groundwater abstraction with groundwater accounting for 41% of irrigation water demand over the last decade. In addition, the CIH is a hotspot for extreme precipitation events and climate change.

India ranks number ten in the world for forested area but only 120th in terms of the percentage of land area under forest. The Forest Survey of India (FSI) conducted in 2019 estimates a total of 807,276 square kilometres of forest and tree cover, which makes up 24.56% of the land area. The 2019 forest area represents an increase of 78,852 (2.4%) square kilometres over the past two decades, with the 1997 Forest Survey of India (FSI) reporting 633,397 square kilometres (19.27%). Given these estimates, India must at a minimum, increase its tree cover by 12% over the next decade, meaning adding 32,874 square kilometres per year on average. The amount of tree cover required is approximately three times the land area proposed within the GIM's stated goals. The magnitude of land cover change required to meet the COP21 commitments, if achieved, has the potential to significantly impact the hydrological cycle of the affected landscapes, with implications for both agricultural production and irrigation potential.

The infiltration-evapotranspiration trade-off hypothesis provides a framework for understanding the possible alteration of the hydrological cycle from reforestation and afforestation. As compared to other land cover, forests have higher rates of evapo-transpiration (ET) but also have higher infiltration and groundwater recharge. The balance between these two depends on a variety of soil, geologic, and land use history, and vegetation attributes. Through greater infiltration, groundwater recharge, and evapotranspiration, forests also reduce peak flows. Likewise, forest compared to other land cover tends to have the lowest annual water yields.

Much of India's cultivable land is devoted to rice production in paddies where infiltration rates are slow, and ET is reduced in comparison to forest. Within the CIH 34% of the land area is devoted to paddy agriculture ranging from 18% to 73% per basin. Rice is grown during the monsoon season with excess water routed through surface drainage instead of percolating to groundwater. Paddy, as a widespread cultivation practice that occupies a considerable land area within each basin, has a significant impact on the amount of groundwater recharge that can subsequently be used for groundwater-based Rabi season irrigation to support multi-cropping and bust agricultural production. Consequently, forest and paddy land covers present very different dynamics in the context of the infiltration-evapotranspiration trade-off hypothesis. Conversion between these two land covers should have a substantial impact on the inter-annual dynamics of the hydrological cycle and availability of groundwater as a consequence of addressing India's COP21 commitments.

Evidence from afforestation and reforestation studies from around the world show divergent impacts on river basins. Most report a decline in basin discharge, with differences in studies between the impact on fast runoff and base flow. Krishnaswamy et al. 2018 report neutral to positive effects of forest cover within a basin on dry-season flow, suggesting forests play a role in the temporal dynamics of streamflow. The reduction in discharge as result of planting trees is largely attributed to the increase in ET. When agricultural land is converted, past cropping intensity and irrigation can have an impact on the ET changes resulting from planting trees. One exception to declining discharge was reported by Lacombe et al., 2016 where teak plantations replaced paddy agriculture in Laos.

Reforestation can also alter dominant flow pathways and dampen streamflow response to precipitation events. Afforestation of agricultural land within the tropics has been shown to have a dramatic impact on infiltration, with between two and four-fold increases Zhang et al. (2019) report an increase in soil hydraulic conductivity in 23-year-old reforested pine, suggesting that soil properties take time to develop post tree planting.

Soil moisture has also been shown to decline after afforestation; this, however, is strongly dependent on the species, density, and phenology of the trees planted. Groundwater recharge is enhanced by the condition of the forest, with plantations providing less recharge than natural forests and conversely an increase in overland flow associated with degradation resulting from overuse. Adjustments to basin hydrology also occur over an extended period after afforestation, with Brown et al., 2013, reporting basins achieving equilibrium after 8 to 25 years and Webb and Kathuria, 2012 reporting maximum streamflow reductions after 14 years. The trade-off between increased infiltration and ET resulting from reforestation can take decades to develop and may never achieve the advantageous balance of natural forest. Afforestation and reforestation have complex impacts on river basin hydrology that play out over both temporal and spatial scales, making them difficult to predict.

India's total cropland area has been largely unchanged since the 1970s, at approximately 60% of the total land area. To meet the ever-growing food demand of the expanding population, India has intensified its agriculture through additional growing seasons that require irrigation. Initial investments for developing irrigated croplands were predominantly in surface-irrigation schemes. In recent years, with bore wells becoming cheaper to drill, expansion of the electrical grid, and provision of pumping subsidies, many farmers have installed bore wells. In some regions of India, this has resulted in an over-exploitation of groundwater resources and a declining water table. While India has ample water resources overall, intra-annual variability can create temporal water stress that limits Rabi season irrigation.

Knowing the balance between water loss and water gain both spatially and temporally throughout the year is crucial in determining synergies or trade-offs between agricultural production and increases in forest cover for carbon sequestration. This paper seeks to answer the following:

- What would be the impact of increasing forest and tree cover within the CIH to 33% of the basin area?
- What type of forest and tree cover yields the maximum groundwater recharge?
- Which hydrological parameters dynamics need to be considered when planning reforestation?

To answer these questions, this paper first examines the impact of land cover on field saturated hydrological conductivity (Kfs) in the CIH. These findings are then incorporated into modified spatial processes in hydrology (SPHY) model for five river basins whose headwaters are within the CIH.

The model is then used to simulate forest cover from 2% through 75% to identify the forest cover required to maximize groundwater recharge. The paper discusses how infiltration and depression storage interact to control groundwater recharge when reforesting paddy-based agriculture landscapes. Lastly, the paper addresses implications for agriculture production and Rabi season irrigation from groundwater sources.

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