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Ecological restoration of village common degraded land through participatory approach for biodiversity conservation and socio-economic development in Indian Himalayan Region

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A B S T R A C T

In the advent of global climate change, ecological rehabilitation through keystone tree species suited to a given socio-ecological conditions has increasingly received wider attention to off-set the global environmental impact through synergizing and enhancing multiple ecosystem services beneficial to human wellbeing. Correspondingly, shortage of forest products and unsustainability of current landuse practices and associated increasing rate of conversion and degradation of remaining natural resources has jeopardized the socio-economic and decision capacity of the farmers residing in Indian sub-continent. Indigenous tree species are largely untried for these applications and represent an underexploited resource that may offer a good combination of adapting local environmental conditions together with potential to restore degraded environments and biodiversity conservation. In view of above, multipurpose tree plantation on village common degraded land in three village cluster viz., Jaminikhal, Manjgaon and Hadiya, district Tehri Garhwal, Uttarakhand, India located across the latitude was established with people participation. The present study reports survival, growth, chemical properties of soil, fodder production and carbon sequestration of four year plantation at three different locations. Average highest survival rate 96.6% was recorded at Jaminikhal village cluster (JVC) compared to Manjgaon village cluster (MVC) 90.3% and Hadiya village cluster (HVC) 71.1%. Average maximum height (147.7 cm) of planted tree species was recorded at JVC followed by MVC (136.2 cm) and HVC (112.2 cm). Annual incremental rate in circumference of the planted tree species across the sites was reported maximum 2.6 cm $year^{-1}$ at JVC while minimum at HVC 2.0 cm $year^{-1}$. Across sites the highest organic carbon %, total nitrogen and total phosphorus 1.06, 0.18 and 0.09 respectively was recorded at JVC and total cation exchange was also reported in the soil of JVC. Fodder biomass from natural grass was harvested maximum (9568 $kg/ha^{-1}/year^{-1}$) at JVC followed by MJV (7546 $kg/ha^{-1}/year^{-1}$) while minimum (6895 $kg/ha^{-1}/year^{-1}$) was recorded at HVC after four year of plantation. Similar pattern was observed for the fodder biomass harvested from introduced grasses and quantified maximum (2856 $kg/ha^{-1}/year^{-1}$) at JVC and minimum (1543 $kg/ha^{-1}/year^{-1}$) at HVC. Appropriate strategies and frame work was developed for successful plantation such as inventorization of bioengineering measures viz., trenches, gully plugging, plantation of fodder grass, people preference for planting species and capacity building of communities for strengthening their understanding and skill to manage plantation sites.

1. Introduction

Ecosystem service is the collective name for the benefits that people obtain from ecosystems. Ecosystem service has been defined from an anthropocentric perspective that links ecosystems and human society by unilateral benefit flows. The impacts of human activity on ecosystem services are most obviously reflected at the local and regional levels. Historically, natural, semi-natural, or managed ecosystems have been able to provide ecosystem services to meet the needs of social development. However, due to the accelerated growth of society, the gaps between the capacity of ecosystems to provide services and human needs are steadily widening [1,2]. Ecosystems in mountain areas provide a range of important ecosystem goods and services (EGS) such as food and fiber production, habitat diversity and protection services [1,3,4]. These services contribute significantly to regional income [5] and without their provision life would hardly be possible in these regions. Most ecosystems in mountain areas are an amalgamation of natural components and components that have been modified by human activity, such as agriculture and forestry [6]. Land-use and associated EGS are therefore dependent on natural processes and external environmental drivers [7]. Land conversion and degradation are very

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serious environmental problems, not only in India but also across the world. The causes, trends, and impacts of land conversion are all closely interrelated. Causes of land conversion are broadly categorized as related to population, personal preferences, policies, developmental activities and economic considerations, and result in impacts such as environmental degradation [8]. Much of the pressure to convert forests to agricultural uses comes from increasing population growth and developmental demands. Restoration of degraded land has been an important item on the agenda since the early 1980s. In order to reclaim degraded and waste land and to meet biomass demands, India launched the Social Forestry Programme in 1980, followed by the more participatory Joint Forest Management (JFM) Programme [9]. Out of 59 million ha land constituting the total geographical area of Indian Himalaya, 7.3 million ha are degraded community lands, 13.5 million ha land are degraded government forests, and 1.2 million has are abandoned private agricultural lands. The effect of land degradation in uplands are felt locally as shortage of food, fodder, and also well away in the Indo-Gangatic lowlands as damage to agriculture, property and human life due to floods. Land degradation threatens biodiversity of the Himalaya, one of the global biodiversity hot spots [10]. Stabilization of rising CO_2 concentration in the atmosphere is the biggest ecological concern to-day the world over [11,12]. Soils are still the largest organic carbon sink on the earth and therefore, sequestration of the atmospheric carbon to soils via plant-conduits by the process of photosynthesis is a viable option for mitigating the global warming. Vegetation is the only source of carbon to the soils in terrestrial ecosystems. The top-down approach prevalent in rehabilitation initiatives until the 1990s has gradually shifted towards community-based forest rehabilitation and management [13]. Rehabilitation of degraded lands in the tropics is important from local as well as national/regional/global dimensions of sustainable development [14,15]. Though numerous land rehabilitation projects have been implemented in the Himalaya, as also elsewhere in the tropics, the impact has by and large been poor because of inappropriate technologies, policies and implementation mechanism [16,17–19]. There are only a few published reports on successful land rehabilitation efforts in the Himalaya but systematic account of costs and benefits are lacking [20,21]. The interplay of ecology, sociology, economics, anthropology and culture needs to be tied together in order to constitute a meaningful rehabilitation strategy. Therefore, successful restoration of degraded landscapes requires the accommodation of different land uses, such as agriculture, tree plantations, and protected landscape areas [6,22–24]. Setting rehabilitation targets in these “multifunctional landscapes” requires addressing trade-offs among a variety of ecosystem services and stakeholders [25]. Given that conservation and avoiding deforestation is no longer sufficient in certain ecosystems to stem the loss of biodiversity and ecosystem services, forest restoration activities should be considered as an important component in national strategies and action plant for degraded land rehabilitation programme. Therefore, the present paper deals with a successful attempt of rehabilitation of degraded community land in three village clusters of Central Himalaya along with detailed analysis of growth and ecological impacts of selected multipurpose tree species over a period of four years in mixed plantations established with people's participation and livelihood improvement.

2. Study area

The present study was carried out in three village cluster viz., Hadiya (30°35′N/78°02′E, altitude 1496 m asl), Jaminikhal (30°16′N/78°36′E, altitude 1532 m asl) and Manjgaon (30°21′N/78°16′E, altitude 1552 m asl) in district Tehri Garhwal of Uttarakhand, India (Fig. 1). The area experiences a typical monsoon climate. Monthly mean minimum and maximum temperatures vary in the range of 7–23 °C and 18–38 °C, respectively. The average annual rainfall is 1700 mm. About 80% of total annual rainfall is received during the monsoon period of July–September. The soil is 30–80 cm deep and of sandy loam to loamy sand texture. The soil is derived from felspathic quartz schists, quartz muscovite schist and quartz chlorite schist [26]. The climax vegetation of the area is sub-tropical warm temperate forest. The village landscape in all three village clusters is differentiated into three broad land use-land cover types: settled farming on privately owned terraced slopes with scattered multipurpose trees, degraded community forest land and degraded abandoned agricultural land. Degraded lands have negligible tree cover and were exposed to uncontrolled grazing. The village clusters are surrounded by government forests. Though two sets of crops, one growing in the warm rainy season and the other in the cold winter season, could be harvested in a year, a farm field is fallowed during the winter season once in a two-year period. Thus, three agricultural crops are harvested over a period of two years [27]. Finger-millet (*Eleusine coracana*), barnyard millet (*Echinochloa frumentacea*) and paddy (*Oryza sativa*) are the dominant crops of the rainy season and wheat (*Triticum aestivum*), lentil (*Lens esculenta*) and rapeseed (*Brassica campestris*) of the winter season. Cash crops such as Potato, Rajma, Cabbage, Tomato, Pea are grown particularly in Manjgaon village cluster since this village cluster has sufficient water resource for irrigation and fertile soil and easy access to market. In village cluster Hadiya, Tomato is cultivated as cash crop in the valley land having moisture in the soil of the agricultural system during the month of October to June. After harvesting of Tomato, these fields are planted with rice in the month of July–August. The number of livestock at household level in all three village clusters is poor as few of the family have a pair of bullock to plow the land. The region has mix forest with dominant species i.e., *Pinus roxburghii*, *Quercus leucotrichophora*, *Lyonia ovalifolia*, *Rhododendron arboreum*. Leaf litter from the forests is used as bedding material in the cattle shed. The litter mixed with cattle excreta is used as manure in the crop fields. Cattle feed is met partly from crop by-products and tree fodder from the private farms and partly from grazing and lopping of fodder trees in the community and government forests.

3. Material and methods

3.1. Identification and procurement of village common degraded land

It is realized that the key to success of ecological restoration programme lies in a concerted effort, bringing together local know-how and innovation with ecological and technical proficiency and the consideration of socio-economic and institutional framework conditions. Linking scientific, technical skill and local knowledge makes it possible to obtain a range of alternative options, including current innovations and new or non-local solutions. Whether new technologies are then accepted and implemented by land users or not depends on factors such as cost effectiveness, severity of degradation, traditional knowledge, framework conditions (e.g., policies and subsidies), and other economic and socio-cultural aspects. It also requires the integration of local and regional authorities, policy makers, civil society organizations, and NGOs. Following these guidance, participatory rural appraisal (PRA) [28,29–31] survey was conducted in three village cluster in district Tehri Garhwal of Uttarakhand for identification and procurement of the village common degraded land to develop rehabilitation models. To this end, an innovative approach in which farmers, researchers, extension workers and government officials were involved together to address the problems in view of rehabilitation programme and come with common solution for better results [2,32]. In contrast to a ‘top down’ approach, farmer involvement was ensured at each stage in formulation and implementation of the programme included; i) a survey of local people perception and indigenous knowledge related to degraded land rehabilitation; ii) analysis people's perception from the perspectives of other stakeholders and their concerns; iii) discussing these perceptions with the people and identifying possibilities for improvement based of scientific knowledge; iv) facilitating consensus for an enhanced rehabilitation framework, and its implementation monitoring (Fig. 2). A total of 450 households representing nearly 60% of households in three