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Community-based Conservation of Multipurpose Tree Species in the Srinagar Hydropower Project Affected Landscape (Garhwal Himalaya) India

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ABSTRACT

This study aimed to conserve some economically important tree species through local community participation in the vicinity of the Srinagar Hydroelectric Power Project (Garhwal Himalaya), India. Through detailed consultation and verification with local people, approximately 21,500 seedlings of the selected tree species (1,535 seedlings/species) viz. *Bauhinia purpurea, B. variegata, Boehmeria rugulosa, Celtis australis, Ficus auriculata, Grewia optiva, Madhuca longifolia, Morus alba, Ougeinia oojeinensis, Syzygium cumini, Terminalia alata, T. bellirica, T. chebula* and *Toona hexandra* were propagated in the nursery. Nursery-raised seedlings were planted by local communities in the vicinity of power project-affected areas. The overall survival percentage of the planted seedlings was 82%. The seedlings of *Syzygium cumini* showed the highest survival percentage (90.83%), followed by *Grewia optiva* (88.40%) under the plantation. Technical know-how on nursery development and conservation has also been provided to local communities through training. Thus, the enhanced plant resources as a result of the plantation of nursery-raised seedlings will help in the improvement of the economy of the inhabitants. Further, increased plant diversity in the area will help manage the region's natural resources and environment.

Key words: Capacity building, Conservation, Garhwal Himalaya, Hydropower project, Local community, Tree species

INTRODUCTION

Indian subcontinent is one of the 12 mega-diversity centers in the world. Eastern Ghat, Western Ghat, North-Eastern and North-Western Himalaya are the most important biodiversity rich regions of India. The Indian Himalaya supports variety of plant resources, which play crucial role in rural livelihood, ecological stability and socio-economic development of the region. The occurrence of about 18,440 plant species in various habitats (Singh and Hajra 1996), 1,748 medicinal plants, 816 tree species (Samant et al. 1998), 675 wild edible plants (Samant and Dhar 1997), 118 essential oil plants with medicinal values (Samant and Palini 2000), 155 sacred plants (Samant and Pant 2003) and 279 fodder plants (Samant 1998) justify the diversity and uniqueness of the region.

The diversity of plants in this area covers the fundamental products like fuelwood, fodder, timber, and medicinal products, which are the foundation of subsistence, livelihood and conventional farming methods (Tiwari et al. 2010). The main source of livelihood in the region is agriculture and animal husbandry. Mixed farming systems prevail because of low arable land, weak soils and few job opportunities. The rural agricultural systems are closely associated with neighboring forest ecosystems which provide fodder, leaf litter, fuelwood and other ecosystem services required to sustain agricultural systems.

However, increasing anthropogenic intervention contributing to terrain instability (Sati et al. 2011) as geology and geomorphology of the area are often neglected during construction activities. Anthropogenic activities *i.e.*, construction and expansion of hill roads, forest fire, over-grazing, lopping of trees for fodder and fuel-wood, removal of litter from the forest and frequent fire are also affecting the plant diversity (Bansal and Mathur 1976, Tiwari et al. 2010, Ballabha 2011, Ballabha et al. 2013a). Most of the species have decreased to a great extent due to over exploitation and habitat degradation (Gupta 1960, Gaur 1999) in the area. The depletion of forest cover, biodiversity and terrestrial carbon stocks, declining farm productivity, increasing hydrological imbalance and soil erosion are interconnected problems and therefore root causes of the poor economic status of the hill people (Chipika and Kowero 2000).

The developmental activities particularly the constructions of Hydroelectric Power Projects are causing a great loss of biodiversity in the region (Samant et al. 2007), which negatively affects the community in the vicinity and environment (Kuniyal and Sharma 2002, Kumar and Kushwaha 2013). The extensive degraded and project affected forest area and farmland requires the necessity of the scientifically-informed conservation techniques and proper restoration technologies (Tiwari et al. 2010, Ballabha 2011, Ballabha et al. 2014, Dhar et al. 1997).

Thus, keeping in view the aforesaid facts, a community-based conservation approach was followed to conserve some multipurpose tree species in the vicinity of Srinagar hydropower project affected landscape of Garhwal Himalayan region.

MATERIAL AND METHODS

Study area

The study area lies between 30^{o} 12’39.73” N - 30^{o} 16’52.23” N and 78^{o} 45’16.53” E - 78^{o} 56’07.83” E, with elevation ranging from 550 - 1400 m amsl (Fig. 1). The proposed study has been implemented in the vicinity of Srinagar Hydroelectric Power Project (Garhwal Himalaya), India (Fig. 2). The Power Project is constructed on the river Alaknanda about 6 km upstream of Srinagar town in district Pauri Garhwal of Uttarakhand state. Physiographically the area consists of hill slopes and valleys of Pauri Garhwal and Tehri Garhwal districts of Uttarakhand with subtropical forests.

The submergence area extends up to about 20 km upstream from the dam. The total land requirement for this project is 475 ha of which 236 ha lies in district Tehri Garhwal and rest i.e., 239 ha is located in district Pauri Garhwal. The total land required for the power project is spread over 24 villages of which 9 villages are in district Pauri Garhwal and 15 villages are located in district Tehri Garhwal. All these villages are located in Alaknanda valley of Garhwal Himalaya in Uttarakhand. Potential site was

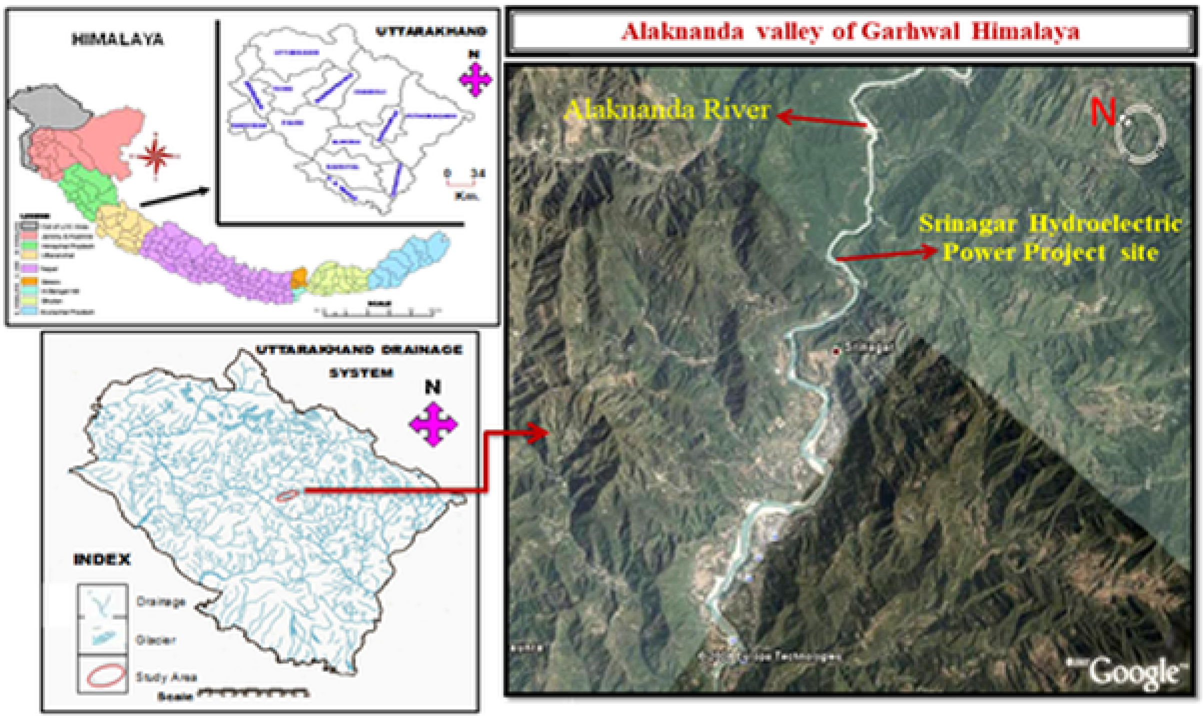

Figure 1. Map of the study area

Figure 2. Srinagar Hydroelectric Power Project under construction on the Alakananda River in Garhwal Himalaya (a & b), Villages in the vicinity of Srinagar Hydroelectric Power Project (c & d)

identified towards the left flank of river Alaknanda in the valley where nursery raising, propagation, multiplication and other research and developmental activities has been carried out to the maximum benefit of local community.

Climate

The area exhibits climate with three distinct seasons, *viz*., summer (March-May), rainy (June-September) and winter (October-February). Mean minimum monthly temperature ranged between 3.39°C (Jan) to 25.69°C (July) whereas, mean maximum monthly temperature ranged between 20.29°C (Jan) to 37.9°C (June). The annual rainfall in the study area was 209.16 mm in year 2010 (Fig. 3).

Community background

The major communities living in the valley are *Garhwalese*. Caste system is also prominent in this area. *Brahmin*, *Kshatriya* and Scheduled Castes (iron smiths and others) are the main casts residing in the valley. Households rely on the direct use of agricultural and forest resources. The major occupation of the local inhabitants is agriculture and is largely practiced through traditional means on steep slopes under rain fed conditions where productivity is low.

Human labour is the most important input in crop cultivation, mainly coming from households itself. Maximum agriculture activities are performed by women except some heavier tasks of land preparation such as clearing, felling trees, burning the debris and to plough the fields. Rest of the activities mainly consisting of manuring, weeding, harvesting collection and storage are performed by women.

Livestock is complementary to agriculture and more so in the hills due to the scarcity of arable land coupled with lesser avenues of employment. Cattle occupy a very important position in the area. Rearing of cows and buffalos is practiced as a part of tradition

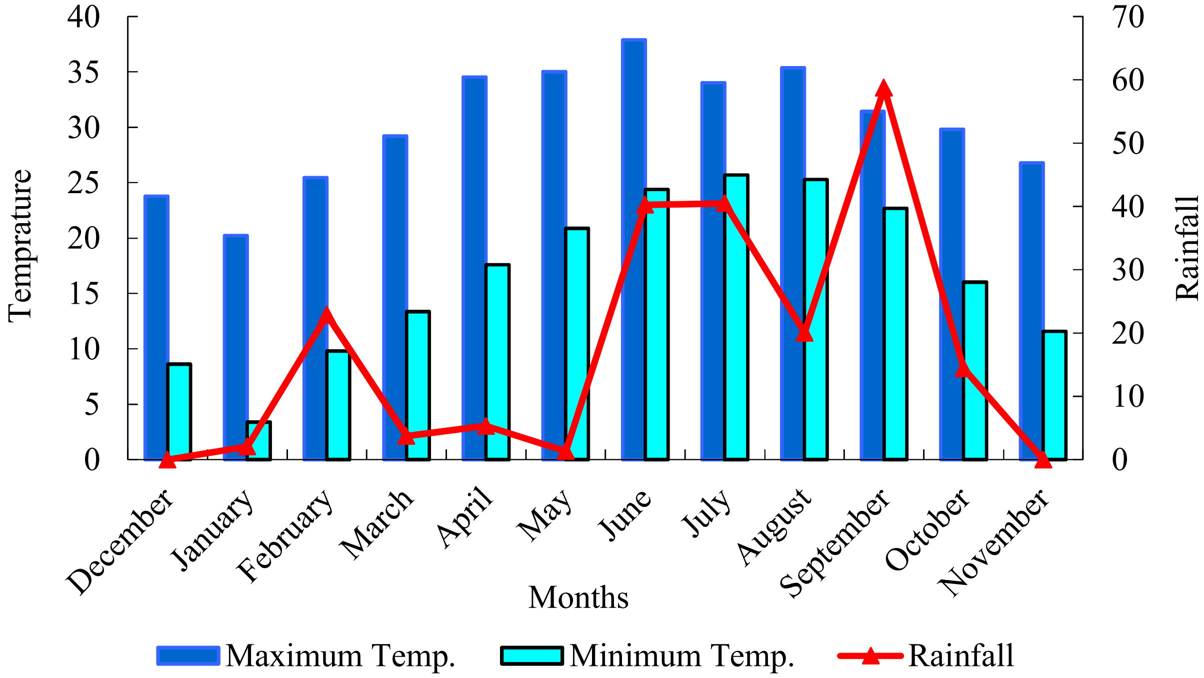

Figure 3. Monthly variation in Min-Max Temperature (°C) and Rainfall (mm) in the study area

Figure 4. Dependency of local people on the forests. Collection of fodder and fuel-wood from the forest (a & b), Cattle rearing and grazing in the area (c & d)

in most of the families (Fig. 4). Economy of local people also depends upon seasonal tourists (*Yatra season*). The migration in search of better livelihood options is very high in the area. A very high number of people are unemployed. Recently, a hydro electric power project has started in the area that is also employing semi skilled and unskilled labours from the villages.

Vegetation composition in the area

The region can be categorized in the sub-tropical vegetational class. The natural forest vegetation of the study area ranges from dense forests to grassy slopes and scrubs. The vegetation is generally composed of either thickly populated broad-leaved forests or scattered coniferous forests at the top of the hills with their corresponding under growth. The vegetation of this area has been grouped in Northern mixed deciduous forest type. *Pinus roxburghii*, *Acacia catechu*, *Mallotus philippensis*, *Lannea cormendelica*, *Holoptelea integrifolia*, *Haldina cordifolia*, *Mangifera indica*, *Anogeissus latifolius*, *Cassia fistula*, *Engelhardtia spicata*, *Erythrina variegata*, *Aegle marmelos*, *Bauhinia purpurea*, *B. variegata*, *Terminalia alata*, *Toona hexandra* and *Ougeinia oojeinensis* are common tree species.

The shrub layer is dominated by *Adhatoda zeylanica*, *Artemisia nilagrica*, *A. capillaries*, *Asparagus adscendense*, *Boehmeria platyphylla*, *Callicarpa macrophylla*, *Carissa opaca*, *Cassia oxidentalis*, *Catunaregam spinosa*, *Colebrookia oppositifolia*, *Euphorbia royleana*, *Eupatorium adenophorum*, *Lantana camara*, *Murraya koenigii*, *Nyctanthes arbor-tristis*, *Reinwardtia indica*, *Rhus parviflora*, *Ricinus communis*, *Woodfordia fruticosa* and *Ziziphus mauritiana*.

Among the herbs *Bidens pilosa*, *Ajuga bracteosa*, *Boerhaavia diffusa*, *Cleome viscosa*, *Cynodon dactylon*, *Dicliptera bupleuroides*, *Euphorbia hirta*, *Lindenbergia grandiflora*, *Micromeria biflora*, *Origanum vulgare*, *Oxalis corniculata*, *Rumex hastatus*, *Stellaria media*, etc. are common species in the study area. Because of little variation in altitude, slope and similar biotic disturbances such as grazing and herbage removal by the local inhabitants, species composition is similar along the whole study area.

Methodology

A detailed reconnaissance survey along with a Participatory Rural Appraisal (PRA) exercise was carried out in the study area. People responses during meetings, group interviews, condition of people and their eagerness, road accessibility, availability of natural resources, waste land and other related aspects were considered to select the land for nursery development and other research and developmental activities. In the survey emphasis was given to the collection of forest-based resources and their interest for developing nursery model in their village. Particularly attention was also paid to identify factors like soil quality and irrigation facilities for nursery development and plantation sites.

Regular field visits were made in the study area in different seasons to collect the seeds and plant propagating materials of selected plant species of economic values. The seeds of selected plant species were collected during 2009 to 2010 from the healthy mature trees growing in the forest. On their maturity the seeds were collected directly from the trees at the time of natural dispersal and transported to the laboratory for processing. Physical damage on seeds was assessed by visual inspection and damaged seeds were discarded to ensure the use of fairly good quality seeds for the study.

The seeds of selected economically important plant species were sown in the mixture medium of sand, dung and clay in the ratio of 1:2:1, respectively in poly bags measuring 7.5 × 25.5 cm. The soil used in the nursery was moderately coarse to fine textured with a grey to olive grey color. The germination of seeds was monitored every 15 days over a period of 90 days from the date of sowing. Weeding was done manually and periodically. Germinated seeds were counted when the seedlings emerged. The emergence of seedlings from substratum was considered as termination of germination.

The local communities (farmers and livestock owners) were motivated and educated through training programs and awareness camps. The plantation of nursery raised seedlings/cuttings of plant species was done by local community participation in the village community and waste land in vicinity of power project affected areas.

RESULTS AND DISCUSSION

Plant diversity is the ultimate source of food, fodder, fuel, medicine, wood, timber, and several non-timber forest products for the people in the region (Tiwari et al. 2010, Ballabha 2011, Ballabha et al. 2014). The reduction of plant diversity on account of increasing urbanization, hill road construction, forest fire, over lopping for fodder, and execution of river valley power projects, is creating several environmental problems (Gaur 2007, Samant et al. 2007, Ballabha et al. 2013b, 2020).

Communal nursery and plantation of the multipurpose tree species in the landscape of the hydropower project area in the Garhwal Himalaya provided promising ecological and socio-economic results. The participatory methods adopted in site selection are household surveys, Participatory Rural Appraisal (PRA), focus group discussions and stakeholder consultations. These were used to guide selection of the site where nursery could be developed. The participatory regime made it possible to be consistent with the patterns of local resource use and community ownership, which is viewed as one of the primary conservation success factors in mountainous ecosystems (Agarwal 2010, Negi 2022).

A nursery has been raised near Rampur village of Pauri Garhwal District of Uttarakhand state at 1200 m elevation (Fig. 5) which lies at 30°13.5' N latitude and 78°51' E longitude. The nursery was used to raise about 21,500 seedlings of the 14 multipurpose tree species successfully. The tree species such as *Bauhinia purpurea*, *B. variegata*, *Boehmeria*

Table 1. Distribution, seed collection period and indigenous uses of the selected plant species for conservation.

Botanical name	Local name	Family	Elevation (m amsl)	Seed collection period	Propagation technique	Indigenous uses
Bauhinia purpurea L.	Guiral	Caesalpiniaceae	Up to 700	Jan - May	Seed	Ed, Fd, Md
B. variegata L.	Kanli	Caesalpiniaceae	Up to 1200	May-June	Seed	Fd, Md, Tm, Fw
Boehmeria rugulosa L.	Genthi	Urticaceae	300 - 1600	Oct-Nov	Seed	Fd, Fw
Celtis australis L.	Kharik	Ulmaceae	Up to 1500	Oct-Dec	Seed	Ed, Fd, Flw
Ficus auriculata Lour.	Timla	Moraceae	Up to 1200	May-June	Seed/cutting	Ed, Fd, Fw
Grewia optiva J. R. Drummond ex Burret	Bheemal	Tiliaceae	Up to 1600	Mar-Apr	Seed	Ed, Fd, Fbr, Md
Madhuca longifolia (Koenig) Mac Bride	Mahwa	Sapotaceae	Up to 1000	June-Aug	Seed/cutting	Fd, Fw, Md
Morus alba L.	Sahtoot	Moraceae	Up to 700	May-June	Cuttings	Ed, Fd
Ougeinia oojeinensis (Roxb.) Hochreutiner	Sandar	Fabaceae	500 - 1500	May-June	Seed	Fd, Md, Tm
Syzygium cumini (L.) Skeels	Jamun	Myrtaceae	Up to 900	June-July	Seed	Ed, Fd, Md, Tm
Terminalia alata Heyne ex Roth	Asin	Combretaceae	Up to 1200	Feb-May	Seed	Fd, Fw, Ag imp
T. bellirica (Gaertn.) Roxb.	Bahera	Combretaceae	Up to 1200	Feb-Mar	Seed	Fd, Md, Tm
T. chebula Retz.	Heda	Combretaceae	Up to 1600	Jan-Feb	Seed	Fd, Md, Tm
Toona hexandra (Wallich ex Roxb.) M. Romer	Toon	Meliaceae	Up to 1000	Apr-May	Seed	Tm, Fd, Ag imp

Ag imp = Agricultural implements, Ed = Edible, Fbr = Fiber, Fd = Fodder, Fw = Fuel- wood, Md = Medicinal, Tm = Timber

Figure 5. Seedlings of *Boehmeria rugulosa* in nursery (a), Capacity building of local community through training and awareness programmes (b)

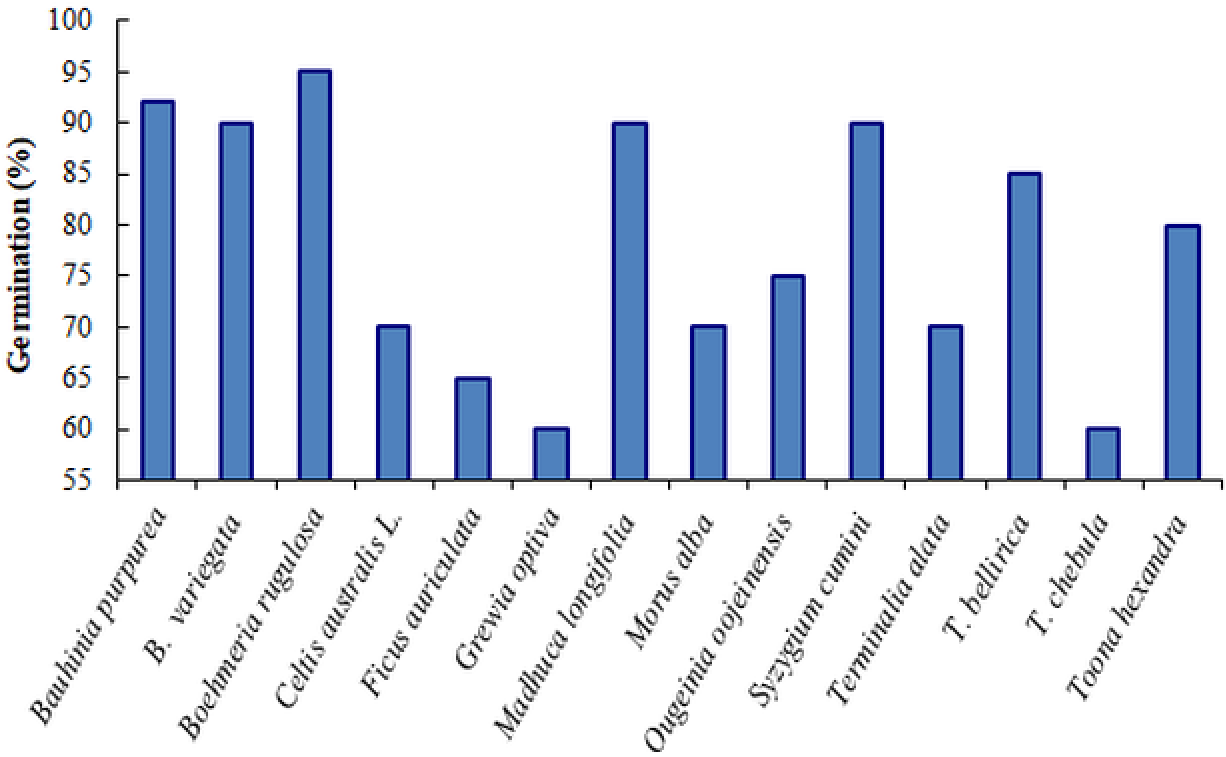

Figure 6. Germination (%) of plant species in the nursery

rugulosa, *Celtis australis*, *Ficus auriculata*, *Grewia optiva*, *Madhuca longifolia*, *Morus alba*, *Ougeinia oojeinensis*, *Syzygium cumini*, *Terminalia alata*, *T. bellirica*, *T. chebula* and *Toona hexandra* were selected for conservation. The distribution and traditional uses of the selected plant species for conservation are given in Table 1.

The percent germination was different in the different species with a range of between 60 and 95% (Fig. 6). *Boehmeria rugulosa* registered the highest germination rate (95 %) followed by *Bauhinia purpurea* (92 %) and *Grewia optiva* and *Terminalia chebula* registered lower germination percentages (60 %). This interspecific variation is in line with previous reports ascribing the variation in germination activities to seed dormancy processes, seed viability and ecological flexibility (Sundriyal and Bisht 1988, Gairola et al. 2011). However, the general success of germination helps to agree that the chosen species and nursery methods are appropriate in the mid-altitudinal conditions of the Himalayan region. After nursery setting, all plantations were transplanted by participation of local community in the area of about 20 ha of village

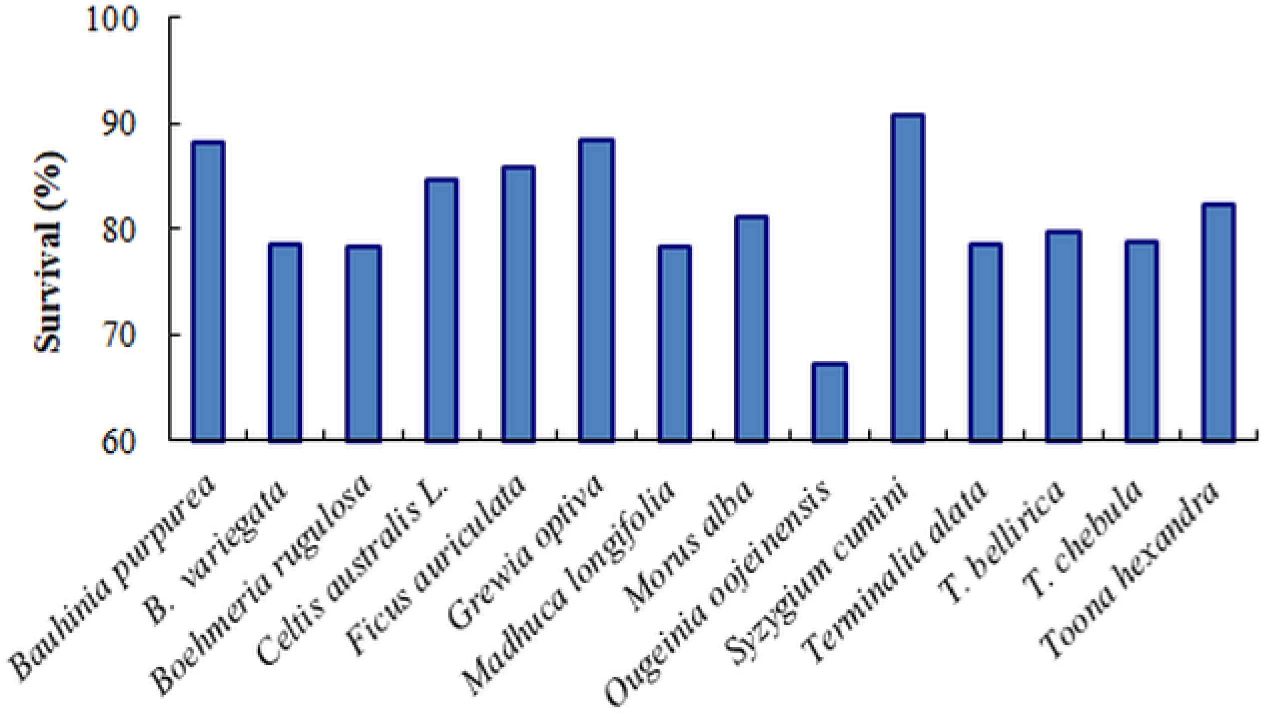

Figure 7. Survival (%) of planted seedlings in the study area

commons and wastelands in the immediate surroundings of the hydropower project affected areas. Monitoring after planting showed that the total survival was 82% and this implied that successful establishment was achieved in the field. Out of all the planted species, *Syzygium cumini* recorded the best survival (90.83%) followed by *Grewia optiva* (88.40%), whereas *Ougeinia oojeinensis* had the lowest survival i.e., 67.33% (Fig. 7). The fodder and fuelwood species have been found more resilient to ecological factors and have high survival rates, which underscores the idea of using ecologically robust species that are socially desirable, which has proven to improve plantation performance in the western Himalaya (Kumar and Ram 2005, Maikhuri et al. 2011). The comparatively good performance of some of the species like *Grewia optiva* and *Syzygium cumini* is especially notable because of the high value of fodder, quality of endurance to lopping and various household applications. Their thriving around village sites will probably lower the strain on neighboring natural forests which are often highly extracted as fodder and fuelwood. Other parts of the Himalayan regions have also reported similar drops in forest dependency after planting communities (Bargali et al. 2022, Negi et al. 2025). The capacity-building interventions were critical in the realization of such results. There were 50 local stakeholders (35 women and 15 men) who received training on nursery development, propagation methods and sustainable harvesting practices. It is also interesting to note that mostly women were the participants since women are the main administrators of forest-based resources in the rural society of Himalayas. Greater technical understanding and skill building did not only lead to a better management of the plantation but also an aspect of stewardship among participants, which underlines conclusions that gender-inclusive conservation approaches are more efficient and lasting (Agarwal 2010). The study shows that conservation combined with livelihood improvement can enhance the resilience of the vulnerable mountainous landscapes. The development of hydropower in the Himalaya has been greatly linked to forest degradation, habitat fragmentation and ecology service disruption (Ballabha et al. 2013a, He et al. 2023).

The current intervention replaces ecological losses linked to big infrastructural projects partially by establishing degraded lands into multipurpose tree plantations, which becomes an alternative resource base. These methods follow the international guidelines that suggest the use of nature-based approaches and community involvement in the sustainable development of mountains (Yadav et al. 2018, Brondizio et al. 2019). Besides ecological benefits, the social-economic benefits that are likely to accrue after the implementation of multipurpose tree planting in the longterm such as better availability of fodder, security of fuelwood and less workload would add to the diversification of livelihood and household welfare. Less time on resource collection especially among women will result in more time to indulge in income generation and social activities resulting in improved quality of life. Similar livelihood gains achieved with agro-forestry and community forestry programs have been reported throughout the Indian Himalaya (Sharma et al. 2025).

In general, the findings suggest that local nursery development and planting of multipurpose tree options can be an efficient tool to revitalize degraded territories, decrease anthropogenic effect on natural forests, and improve socio-ecological stability of landscapes affected by hydro power activities in the Himalayas. The strategy presents a repeatable template in the application of integrating biodiversity conservation and sustainable livelihoods in other less vigorous mountain areas that consequently experience the same developmental pressure.

CONCLUSIONS

The present work demonstrates that nursery development and planting of multipurpose tree species in the community is a viable ecological restoration approach to the hydropower development project impacted areas of the Garhwal Himalaya. The effectiveness of the propagation of 21,500 seedlings belonging to 14 species with germination rates between 60 and 95% with the overall success, which was eighty two percent, was the indication of the suitability of the local adapted species and nursery practices in the conditions of the mid-altitudes in the Himalayas. Community involvement in activities, especially with women, could not have been achieved without specific capacity-building, especially with women, to enhance technical capacity, foster sustainable harvesting, and enhance management of forest assets. Settlement on village commons and wastelands offered a source of fodder and fuelwood, which was easily accessible and thus would take the strain off the natural forests and soft-land development would alleviate the ecological stress caused by development.

The findings of the present investigation would also be helpful to the Forest Department, forest managers and scientists for developing strategies and preparing action plans for the management and conservation of this biodiversity rich forest area. Further, the following points are suggested for the conservation of the plant diversity of the area: Participants should be introduced appropriate technology requiring environmental impact assessment of proposed hydroelectric power projects likely to have significant adverse effects on biological diversity with a view to minimizing such effects and, where appropriate, allowing local communities' participation in such procedures; New technology needs to be developed for the conservation of plant diversity through the combination of indigenous and traditional knowledge with scientific and technical research; Public awareness should be made by field-oriented training program organized at the local level for community participation in various bioregions delineated for inventorying; Large scale cultivation of economically important plant species by local communities should be encouraged to minimize the pressure on natural habitats.

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