J. Mountain Res. P-ISSN: 0974-3030, E-ISSN: 2582-5011 DOI: https://doi.org/10.51220/jmr.v20-i1.16
Vol. 20(1), (2025), 147-162

Greening Urban Landscape for Ecological Diversity and Sustainability: Toronto Example

V.P. Upadhyay*

Adviser (Rtd.) Govt. of India, Ministry of Environment, Forest and Climate Change, Bhubaneswar-751 023.India

*Corresponding Author Email Id: vpupadhyay@gmail.com

Received: 23.02.2025; Revised: 18.05.2025; Accepted: 01.06.2025

Abstract: Forests have traditionally been managed primarily for timber, sidelining the ecological and economic value of non-timber forest products (NTFPs). However, NTFPs offer a sustainable pathway for conservation by promoting biodiversity, reducing pressure on timber resources, and enhancing ecosystem resilience. Urban forestry programs often prioritize exotic tree species for afforestation, which may lead to ecological imbalances and climate vulnerability. This paper explores the ecological principles underlying sustainable urban greening, using the Greater Toronto Area and Vaughan City in Canada as case studies. It emphasizes the selection of native tree, shrub, and herb species and the adoption of ecologically sound planting and maintenance practices. Comparative insights are drawn from Indian Himalayan ecosystems, highlighting the potential for replication of these practices in ecologically fragile landscapes. A framework for integrating biodiversity conservation with urban development and restoration is proposed to enhance ecological function and sustainability in both urban and mountainous environments.

Keywords: Biodiversity • Non-Timber Forest Products • Urban Forestry • Himalaya • Mulching • Native Species • Sustainable Development

Introduction

Global and national efforts for environmental protection include action plans, legal frameworks, and international treaties aimed at conserving vital resources. Agreements addressing marine and ocean resource conservation, biodiversity, desertification, ozone depletion, and climate change emphasize the interconnected nature of environmental challenges, often leading to multiple, cumulative effects on ecosystems. Conventions regulate transboundary hazardous waste movement, marine waste dumping, and the protection of Antarctica's resources. The Convention on Biological Diversity is a landmark initiative promoting conservation and sustainable resource use.

Forests, rich in endemic and ethnobotanical value, are under severe pressure due to population growth, deforestation, and commercial exploitation. Without timely restoration, these ecosystems may collapse. Initiatives like community forestry, joint forest management, and eco-development aim to balance conservation with community needs. However, forest benefits have often come at the cost of upper vegetation layers—primarily trees for timber (Ros–Tonen et al., 1995). This paper advocates urban greening through ecological principles to support sustainable development and enhance national GDP.

Methodology

This study adopts a qualitative, case-study-based methodological approach to explore the role of non-timber forest products (NTFPs) in promoting biodiversity conservation and urban ecosystem sustainability. Two urban greening models—Greater Toronto and Vaughan City in Canada—were selected as case examples

DOI: https://doi.org/10.51220/jmr.v20-i1.16

due to their demonstrated use of ecological principles in urban forestry.

Field visits, photographic documentation, and informal discussions with forestry officials and community volunteers were conducted during urban plantation programs in 2024. Species composition, planting techniques, mulching practices, and community engagement protocols were directly observed and recorded. Existing literature, municipal greening plans, and publicly available species inventories were reviewed to understand policy frameworks and ecological strategies.

Rapid Vulnerability Assessment (RVA) and ecological principles such as species stratification, carrying capacity, and native biodiversity regeneration were used to analyze species selection and planting design. Insights from these practices were compared with the forest and plantation conditions in the Indian Himalayan region, particularly in Uttarakhand and Himachal Pradesh.

The methodology combines observational analysis, comparative ecology, and applied restoration principles to assess transferability of urban greening practices to fragile mountainous landscapes

Observations and Discussion

Urban Expansion and Resource Exploitation: Urban expansion and growing energy demands have significantly stressed India's forest resources. Reports indicate that the extraction of timber and fuelwood has already surpassed the forests' carrying capacity. While the estimated annual production capacity is 42 million m^3 for timber and 19 million m^3 for fuelwood, industrial demand is expected to reach 98 million m^3 by 2030, up from 57 million m^3 in 2020. Currently, forests contribute only 59 million tonnes (MT) of the 216 MT of total fuelwood used, indicating a sustainable supply of less than 23% for fuelwood and 43% for industrial wood (Kant and Nautiyal, 2021).

Globally, the economic value of non-timber forest products is considerable. For instance, rattan and oil exports were valued at US $200 million in Indonesia, US $11 million in Peru, and between US $14–52 million in Ecuador, Bolivia, and Brazil (ITTO, 2002). Against this backdrop of resource depletion, assessing the ecological sustainability of urban development becomes critical. This requires data on ecosystem structure, population dynamics, and interactions between species and their abiotic environment. Harvesting must remain within ecological limits to avoid disrupting population regeneration and ecosystem functioning. Sustainable harvesting techniques and an understanding of plant regrowth and reproduction dynamics are essential. Exploitation within regenerative capacity ensures ecosystem resilience. Population growth models are vital tools to determine critical harvest levels and enhance output through managing natality, reproduction, and mortality. Genetic erodibility must also be considered before exploitation. Forests provide tangible benefits like timber, food, and medicine, as well as intangible ecological and cultural services. Urban forests often focus on single species for aesthetics, but broader ecological functions must be valued. As Pears (1993) noted, forests hold direct use value, indirect ecological value, option value for future use, and existence value—each essential for truly sustainable urban development.

Adopting Ecological Principles for Urban Greening

Urban greening must integrate ecological principles to ensure biodiversity conservation and sustainable urban ecosystems. Deforestation leads to loss of forest-dependent livelihoods, biodiversity, and climate stability. Urban forestry programs should prioritize vulnerable species identified through Rapid Vulnerability Assessments (RVA) and field-based ecological evaluations using sustainability criteria. Applying ecological concepts such as carrying capacity helps select suitable species for long-term productivity. Large, low-density species are particularly prone to overexploitation and need targeted conservation efforts. In addition to planting in urban areas, managing nearby natural habitats can enhance regeneration of valuable species through protection of natural regeneration, coppicing, root sprouting, transplanting seedlings, and seeding. Buffer zones around cities and protected areas play a vital role in conserving biodiversity and stabilizing urban environments. Raising awareness among local communities can prevent encroachment and promote sustainable income opportunities without disrupting ecosystem functions. Promoting biologically rich forests in buffer zones supports resilient urban ecosystems and protects species-rich core areas.

Sustainable Approach for A Green Urban Ecosystem

Green Toronto Initiative: There are numerous voluntary environmental organizations helping their respective countries to enhance the green cover as an effective means to counter climate change. The Natural Environment & Community Programs unit of City of Toronto Forestry offers a number of free programs to grow and maintain Toronto's urban forest through public engagement. This work includes organizing free community tree planting and stewardship events in Toronto parkland spring through fall every year. Staff work with volunteer participants to plant native trees, shrubs, and wildflowers to grow Toronto's urban forest. On 10th October 2024, and 19th October 2024, Planting was done by volunteers selecting native species of trees, shrubs and herbs (Table 1). Trees in prominence were potential natural species like *Quercus macrocarpa, Ribes nigrum* and *Thuja occidentalis*, all native to Canada. Other species like Maple etc. were also planted by volunteers during the events. These events acted also as a platform for people to learn more about native trees, shrubs and invasive species, learn how to plant a tree, take part in environmental stewardship activities, meet new people, make new friendships and network within the community and gain experience, and leadership and interpersonal skills.

The Bestview Park planting event at 115, Bestview Dr, North York, Toronto, Ontario was also utilized by the author V. P. Upadhyay to inform the participants about "EK PED MAA KE NAAM" (one plant in the memory of mother), the massive voluntary citizen's greening drive in India. The planting methodology and species selection have been ecologically very sound. From the **Table 1**, it can be seen that like natural forest, species of all three strata viz., tree, shrub and herb were chosen for planting. These species will help the area to attain the status of climax community and landscape will merge with the natural surrounding ecosystem, thus creating more space for flora and fauna to interact with each other. Planting protocol adopted during the programmes is wearing gloves, using plastic containers which are reusable, making pit of the little bigger size of the seedling pot and spreading wood mulch and wood mat in almost one foot radius of planted seedlings **(Photo 1).**


Photo 1. Plantation by volunteers in Best view Park(left) and White Haven Park(right) Toronto

The seedlings plot has inner surface so smooth that intact soil and OM along with seedlings comes out without any damage to fine roots which enables the seedling to grow and establish itself. After planting, the mat is placed on the filled pit followed by thick wood mulch. These interventions have two advantages: first the weeds are not able to grow around the pit and second slow decomposition of mulch will provide required nutrients to seedling in initial phase of establishment. The mat also protects the roots from snow or cold temperatures to survive. These precautions will ensure success in growth of the plantation. When applied during the growing season, mulches help control weeds by suppressing seed germination and by weakening the growth of young perennial weeds. In these ways, mulch helps to reduce our reliance on herbicides. In summer, mulches also help retain moisture in the soil, which encourages plants to develop deep, self-sufficient roots rather than shallow ones that are more reliant on supplemental watering. Mulches also help to moderate the soil temperature, thereby reducing the stress of extreme temperature fluctuations on plants.

Table1. Planting events at two sites organized by City of Toronto Urban Forestry in October 2024.

BESTVIEW PARK MAIN	**WHITE HAVEN PARK**
Intersection: Bestview Dr & Laureleaf Rd S	Urban Forest Renewal Main Intersection: lnvergordon Ave & Glenstroke Dr
Infill planting in previously naturalized area.	Creating naturalized node beside mature park trees on mound at southern end of park.
Trees 40 ; Shrubs 170 ; Herbs75 ;Total 285	Trees 45 ; Shrubs 310 ; Herbs 30; Total 385
Trees 1. *Acer saccharinum 5 Maple, silver* 2. *Acer saccharum 5 Maple, sugar* 3. *Betula papyrifera Birch, white 6* 4. *Populus tremuloides Aspen, trembling 6* 5. *Prunus serotina Cherry, black 6* 6. *Quercus alba Oak, white 6* 7. *Thuja occidentalis* Cedar, white 6 **Shrubs** 1. *Cornus sericea 15Dogwood, red-osier* 2. *Physocarpus opulifolius Ninebark 15* 3. *Potentilla fruticosa Shrubby Cinquefoil 10* 4. *Prunus virginiana 15 Cherry, choke*	**Trees** 1. *Acer saccharum Maple, sugar 6* 2. *Betula papyrifera Birch, white 7* 3. *Cercis canadensis Redbud 6* 4. *Pinus strobus Pine, Eastern white 6* 5. *Populus tremuloides Aspen, trembling 7* 6. *Quercus macrocarpa Oak, bur 6* 7. *Thuja occidentalis Cedar, white 7* **Shrubs** 1. *Amelanchier laevis Serviceberry, 25 (Smooth Shadbush, Allegheny serviceberry)* 2. *Cornus racemosa 25 Dogwood, Grey* 3. *Cornus sericea 25 Dogwood, red-osier*

5. *Ribes americanum 15 Currant, Wild Black* 6. *Rosa blanda 15 Rose, smooth* 7. *Rubus allegheniensis Blackberry 10* 8. *Rubus occidentalis Raspberry, black 20* 9. *Rubus odoratus Raspberry purple flower 10* 10. *Salix bebbiana Willow, bebb's 15* 11. *Sambucus canadensis 15 Elderberry, Common* 12. *Viburnum lentago 15 Nannyberry* **Herbs** 1. *Anemone, Canada Anemone canadensis 15 (meadow anemone)* 2. *Carex pensylvanica 15 Pennsylvania Sedge* 3. *Panicum virgatum 15 Switch Grass* 4. *Symphyotrichum ericoides Heath Aster 15 (syn. Aster ericoides)* 5. *Symphyotrichum leave Smooth Aster 15 (syn. Aster laevis)*	4. *Diervilla lonicera 25 Bush honeysuckle* 5. *Physocarpus opulifolius Ninebark 30* 6. *Prunus virginiana 30 Cherry, choke* 7. *Rhus typhina 15 Sumac, staghorn* 8. *Rosa blanda 20 Rose, smooth* 9. *Rosa carolina 30* 10. *Pasture Rose Rubus occidentalis 35* 11. *Raspberry, black Rubus odoratus 40 Raspberry, purple flowering* 12. *Sambucus racemosa Elderberry, red-berried 10* **Herbs** 1. *Carex pensylvanica Pennsylvania Sedge 10* 2. *Solidago flexicaulis Zigzag Goldenrod 10* 3. *Symphyotrichum ericoides Heath Aster 10 (syn. Aster ericoides)*

Organic mulches also enrich the soil, improve its texture and increase the water-holding capacity of sandy soils and the porosity of clay soils. The Mulches may include components like compost, tree bark, wood chips, leaves grass clippings Pine needles, straw or sawdust. A thick layer of mulch applied to plants periphery over the soil pit helps to insulate the ground, keeps soil temperatures to prevent soil to freeze and thaw as temperatures fluctuates during winter seasons. As all organic mulches decompose, their periodic reapplications are practiced in urban plantings. Mulch is a protective layer of organic material spread on top of soil to improve the health of plants and soil. It is a system primarily encouraged for soil hydration, insulation, and nourishment.

Wood mulch with high carbon, lignin and other recalcitrant substances may restrict release of N and other essential nutrients to the soil depending on decomposing microbial activity. Upadhyay and Singh (1985) observed that higher initial N concentration caused the C:N ratio to approach the critical level (from where net mineralization starts) more rapidly. Net N release started between C: N ratios of 15: 1 and 35: 1 in *S. robusta, Q. glauca, R. arboreum, Q. lanuginose* and *Q. floribunda* and at C: N ratios of 47: 1 and 55: 1, respectively, in *P. roxburghii* and *Myrica esculenta*. Initial N concentration was much lower in the latter species. Swift, Heal & Anderson (1979) argued that when N contents are low, carbon is respired but N is immobilized into microbial biomass. Lutz and Chandler (1946) reported that critical C: N generally range from 20 to 30. At ratios greater than the critical ratio, N is immobilized, while at smaller ratios it is released or mineralized. Berg and Ekbohm (1983) found critical C: N ratios to be 63: 1 and 109: 1 for decomposing Scots pine needles in two habitats. So, wood mulch from conifers may cause deficiency of N for the planted species and microbes will take long period to transform the material to reach to critical C: N ratio from where nutrient release by decomposition will begin.

Wood Mulch Quality and Ecological Impact: Wood mulch, while commonly used in landscaping, can pose significant ecological risks depending on its source and chemical treatment. According to Larum (2023), mulches made from wood treated with chromated copper arsenate (CCA) may leach arsenic into the soil. Additionally, stored wood mulch can release toxic substances like methanol, acetic acid, ammonia, and hydrogen sulfide—chemicals potentially more hazardous than conventional pesticides. Fresh mulch also tends to be highly acidic (pH 1.8–3.6) and can deplete nitrogen from soil during microbial decomposition, leading to plant stress such as yellowing, leaf scorch, defoliation, or even plant death.

Dyed mulches require careful evaluation. While red and black mulches are dyed using iron oxide and carbon respectively, their safety hinges on the wood's origin. Mulch from natural, untreated wood dyed with organic dyes is generally safe. However, dyed mulches from recycled or chemically treated wood (e.g., pallets) can harm wildlife like sparrows, rabbits, and geese. Gohring (2021) recommends using shredded fallen leaves, alone or mixed with untreated wood chips, as a safer alternative. Another ecological concern is the extensive use of de-icing salts on urban roads in winter. Runoff from salted surfaces increases soil salinity, adversely affecting salt-sensitive plant species. This may also reduce overall urban biodiversity, warranting long-term ecological studies.

Inventory of Alien Invasive Plant Species

A list of alien invasive plants of greatest concern that are problematic in specific area need to be checked with local experts and research scientists to exclude these from plantation activities. These plants will often become invasive in particular climatic and site conditions and become an aggressive invader affecting climate and ecology of the area. **Table 2** list out invasive species for caution during greenery development in local areas. These inventories are readily available and such species could be avoided in taking up plantation especially close to natural forests or parks.

Community Sustainability Plan – Green Directions Vaughan: An exemplary urban greening initiative is the approach adopted by *Green Directions Vaughan*. Vaughan, part of the Regional Municipality of York, became a city on January 1, 1991, and is now the fifth-largest city in the Greater Toronto Area. Within just 25 years, Vaughan has successfully promoted urban greenery by establishing native plant species along urban corridors and in both commercial and residential areas. A major portion of Vaughan's *Protected Countryside* is designated as a *Natural Heritage System*, consisting of core and linkage areas with high ecological significance (OPR 2022). With a population of 340,700 in 2021, and projected to account for nearly one-third of York Region's future growth, the city has planned strategically for sustainable urban expansion.

Vaughan's *Urban Design Guidelines*, aligned with its Official Plan, promote the "Green Approach" — creating interconnected green spaces, edges, and buffers to enhance the natural system and urban canopy. Over 40% of Vaughan's land comprises natural heritage, conservation, and parkland. Under the *Community Sustainability Plan – Green Directions Vaughan* (2019), 12,000 trees were planted in 2017–18. Key actions include:

-Revitalizing Edgeley Pond as central green space in Vaughan Metropolitan Centre

-Managing 800+ hectares of public green areas

-Protecting over 6,000 hectares identified in the Natural Heritage Network Study.

Interpretation for the City of Vaughan: The *Vaughan Official Plan 2010 (VOP 2010)* maps natural areas as part of the *Natural Heritage Network*, which includes woodlands, wetlands, and valley lands. This network spans over 6,000 hectares, covering approximately 20% of Vaughan's land area. About half of this land is publicly owned by the City or the Toronto Region Conservation Authority (TRCA). However, woodlands constitute only 11%, and wetlands just 1% of the city's total land area. Thus, much of the network consists of meadows, open fields, and successional habitats, often found in valleys or near streams on agricultural land, presenting significant opportunities for ecological restoration and habitat enhancement. Additionally, city-owned lands like *North Maple Regional Park*, though not part of the designated Natural Heritage

Network, offer further restoration potential. These areas can support passive recreational activities such as hiking and cycling, while contributing to Vaughan's broader environmental and ecological goals.

Urban Forest and Tree Canopy: Trees and forests offer vital ecosystem services, including oxygen production, pollutant removal, shade, and cooling through evapotranspiration. TD Economics (2014) estimated the value of Toronto's urban forest at $7 billion—about $700 per tree—delivering environmental benefits of $8 per tree, which translates to roughly $125 in annual household savings. Woodland cover refers to forest stands over 0.2 hectares, while total tree canopy includes individual trees in boulevards, parks, and private lots. For Vaughan, the recommended woodland cover is 14–17%, and total canopy cover is 25–35%. Currently, Vaughan has 11% woodland cover. Reaching the 14–17% target will require planting trees on an additional 800–1,600 hectares, ideally in open valley lands, meadows, and successional habitats (Green Directions 2019). Tree canopy in Vaughan stands at approximately 17%, but it has been reduced by recent ice storms and losses from the invasive Emerald Ash Borer. The city's recent tree canopy inventory provides a baseline for focused improvements, including planting along boulevards for "green streets," increasing shade in parks, and mitigating the urban heat island effect in densely developed areas. Smith (1981) studied pollutant absorption by vegetative surfaces and modeled a forest hectare using species like maple, oak, poplar, linden, birch, and pine—all of which are used in Vaughan. His model predicted annual pollutant removal of O_3 – 9.6 × 10^4 tonnes, SO_2 – 748 tonnes, CO – 2.2 tonnes, NO_x – 0.38 tonnes, and PAN – 0.17 tonnes, underscoring the role of tree species selection in maximizing ecological benefits.

Plantation of Residential Areas: In Vaughan's residential and commercial zones, urban plantation includes aesthetically and ecologically valuable species such as Linden (*Tilia cordata*), Tulip Tree (*Liriodendron tulipifera*), Paw Paw (*Asimina triloba*), Catalpa (*Catalpa speciosa*), Weeping Beech (*Fagus sylvatica*), Viburnum, Burning Bush (*Euonymus alatus*), Honeysuckle (*Lonicera caprifolia*), Buck Fern (*Lastrea rigida*), Crab Apple (*Malus sylvestris*), Columnar Oak, Blue Spruce, Japanese Maple, and some *Pyrus* species. These species are widely appreciated for their ornamental value and compatibility with urban landscaping. Dyed wood mulch in brown, red, or black shades is commonly observed around trees in residential yards.

Species listing (Table 3) indicate that most species used are native to Canada and found in protected forest areas. A digital inventory of invasive species, coupled with community awareness efforts, helps guide planting choices away from ecologically harmful species. Regular maintenance, including the application of mulch beneath older plants, is visible throughout the city's landscapes. Mulch helps retain soil moisture, especially for lateral root systems that extend well beyond the canopy drip line. Vaughan's practice of extending mulch to the canopy's edge maximizes nutrient and moisture absorption. The use of compatible groundcovers as "living mulch" further enhances sustainability (Crawford and Cabrera, 2021). While inorganic mulches like gravel, lava rock, and shredded rubber are common in office complexes for decorative appeal, they can cause soil compaction, increase heat loads, and release of harmful chemicals, potentially raising soil pH. Therefore, such materials should not be used.

Table 2. Alien invasive non-native plant species inventory at a few locations in Canada.

Alien Invasive Plant Species	
The Lower Mainland, Vancouver Island and the Gulf Islands	The Interior region
Buddleia davidii - Butterfly bush *Cytisus scoparius* - Scotch broom** *Daphne laureola* - Spurge laurel *Hedera helix* - English ivy *Ilex aquifolium* - English holly *Polygonum cuspidatum*-Japanese knotweed or bamboo *Rubus discolor* - Himalayan blackberry *Senecio jacobaea* - Tansy ragwort *Ulex europaeus* - Gorse *Lythrum salicaria*- Purple loosestrife (aquatic plant)** *Spartina pantens - Salt-meadow grass (in salt marshes)*	*Acroptilon repens*- Russian knapweed** *Centaurea biebersteinii*- Spotted knapweed** *Centaurea diffusa*- Diffuse knapweed** *Chondrilla juncea*- Rush skeletonweed** *Cirsium palustre*- Marsh thistle *Cirsium arvense*- Canada thistle *Cynoglossum* officinale- Hound's tongue *Euphorbia esula*- Leafy spurge** *Linariagenistifolia/.dalmatica*-Dalmatian toadflax** *Hieracium aurantiacum*- Orange hawkweed *Potentilla recta*- Sulphur cinquefoil** *Tribulus terrestris*- Puncturevine *Elaeagnus angustifolia*- Russian olive (tree) *Lythrum salicaria*- Purple loosestrife (aquatic plant)** *Myriophyllum spicatum*- watermilfoil -aquatic .plant*

***Of particular concern – very aggressive, or potential threat to sensitive ecosystems*

Source:**https://networkofnature.org/userContent/documents/Local%20Species%20Lists/Recommended%20Native%20Species%20List%20-%20BC%20Nature.pdf**

Table 3. Natural vegetation in forests of Canada

Tree species	
White Pine - *Pinus strobus* Red Pine - *Pinus resinosa* Jack Pine - *Pinus banksiana* Black Spruce - *Picea mariana* White Spruce - *Picea glauca* Balsam Fir - *Abies balsamea* White Cedar - *Thuja occidentalis* Larch (Tamarack*)* - *Larix laricina* Hemlock - *Tsuga canadensis* Poplar (Aspen*)* - *Populus species* White Birch - *Betula papyrifera* Sugar Maple - *Acer saccharum* Red Maple - *Acer rubrum* Oak - *Quercus species* Yellow Birch - *Betula alleghaniensis* Ash - *Fraxinus species* Sitka Mountain Ash *(Sorbus sitchensis)* Western Red Cedar *(Thuja plicata)* Western Hemlock *(Tsuga heterophylla)* European Mountain Ash *(Sorbus acuperia)*	Grand Fir *(Abies grandis)* Vine Maple *(Acer circinatum)* Douglas Maple *(Acer glabrum)* Big-leaf/Broadleaf *(Acer macrophyllum)* Red Alder *(Alnus rubra)* Paper or White Birch *(Betula papyrifera)* Black Hawthorn *(Crataegus douglasii)* Western Crabapple *(Malus fusca)* Pacific Crabapple *(Malus diversifolia)* Sitka Spruce *(Picea sitchensis) wetlands* Lodgepole or Shore Pine *(Pinus contorta)* Ponderosa Pine *(Pinus ponderosa)* Black Cottonwood *(Populus balsamifera)* Trembling Aspen *(Populus tremuloides)* Bitter Cherry *(Prunus emarginata)* Pin or Bird Cherry *(Prunus pensylvanica)* Choke Cherry *(Prunus virginiana)* Douglas Fir *(Pseudotsuga menziesii)* Garry or Oregon Oak *(Quercus garryana)* Cascara *(Rhamnus purshiana)* Pussy Willow *(Salix discolor)* Pacific Willow *(Salix lucida spp. lasiandra)*
Shrubs and Shrubby Trees	
Sitka or Slide Alder *(Alnus sinuata* Saskatoon Serviceberry *(Amelanchier alnifolia)* Red-Osier Dogwood *(Cornus stolonifera* Beaked Hazelnut *(Corylus cornuta)*	Prairie Rose *(Rosa woodsii)* Thimbleberry *(Rubus parviflorus)* Salmonberry *(Rubus spectabilis)* Scouler's Willow *(Salix scouleriana)* Sitka Willow *(Salix sitchensis)*

Salal *(Gaultheria shallon)* Ocean Spray *(Holodiscus discolor)* Black Twinberry *(Lonicera involucrata)* Tall Oregon Grape *(Berberis aquifolium)* Indian Plum *(Oemleria cerasiformis)* Mock Orange *(Philadelphus lewisii)* Pacific Ninebark *(Physocarpus capitatus)* Nootka Rose *(Rosa nutkana)* Clustered Wild Rose *(Rosa pisocarpa)*	Blue Elderberry *(Sambucus cerulea)* Red Elderberry *(Sambucus racemosa)* Hardhack *(Spirea douglasii)* Snowberry *(Symphoricarpos albus)* Evergreen Huckleberry *(Vaccinium ovatum)* Red Huckleberry *(Vaccinium parvifolium)* Shrubby Cinquefoil *(Potentilla fruticosa)* Red-FloweringCurrant *(Ribes sanguineum)*
Ground Covers, Wetland Plants and Herbaceous Perennials	
Kinnikinnick (*Arctostaphylos uva-ursi*) Western Maidenhair Fern (*Adiantum aleuticum*) Western Columbine (*Aquilegia formosa*) Lady Fern (*Athyrium filix-femina*) Low Oregon Grape (*Berberis nervosa*) Deer Fern (*Blechnum spicant*) Lyngby's Sedge (*Carex lyngbyei*) Slough Sedge (*Carex obnupta*) Beaked Sedge (*Carex rostrata*) Canada Bunchberry (*Cornus canadensis*)	Skunk Cabbage (*Lysichiton americanum*) FalseLily-of-the-Valley(*Maianthemum dilatatum*) Sword Fern (*Polystichum munitum*) Hardstem Bulrush(*Scirpus acutus or lacustris*) Seacoast Bulrush (*Scirpus maritimus*) Small-Flowered Bulrush (*Scirpus microcarpus*) False Solomon's Seal (*Smilacina racemosa*) Cattail (*Typha latifolia*) Common Rush (*Juncus effusus*) Twinflower (*Linnaea borealis)*

Planting Activity in the Indian Himalayan Region: Early human settlements in the Indian Himalayas, nestled within continuous forest stretches, consisted of small houses and croplands surrounded by open grazing lands. As these settlements expanded, locals began planting native fodder tree species like *Grewia optiva* (Bhimal) and bamboo for their high foliage protein content. However, large treeless stretches now dominate these landscapes, dotted with scattered, degraded broadleaf trees and sparse chir pine stands. Invasive species such as *Lantana camara* and *Cactus* have infested pine regions up to 1500 m. The loss of tree cover has left soils exposed, leading to erosion, a drier microclimate, vanishing springs, and disappearing streams. To transition these semi-arid regions of the Central Himalaya into mesic, forested environments, effective ecological restoration strategies are essential. Models like the Green Toronto and Vaughan programs offer valuable insights for planning afforestation in Uttarakhand. Restoration must prioritize native species suited to specific altitudes and local soil and climatic conditions. The Uttarakhand Forest Department recommends altitude-specific species (www.gramya.in):

a) *400–1000 m*: Aam, Ailanthus, Amaltas, Ashoka, Bamboo, Neem, Shisham, Teak, etc.
b) *1000–2000 m*: Banj, Burans, Deodar, Chir, Kafal, Kail, Padam, Ritha, Poplar, etc.
c) *2000 m and above*: Deodar, Fir, Spruce, Kharsu, Moru.

Proper species selection based on elevation and aspect is critical for successful plantation. A science-based, location-specific afforestation strategy is key to ecological resilience and water security in the fragile Himalayan ecosystem.

Table 4: Plantation Raised in Himachal Pradesh in various years. (https://hpforest.gov.in/plantation)

Common name/ Botanical name	Recommended plantation species*
Deodar(*Cedrus deodara),* Kail, Fir/Spruce,Chil, Khair*(Acacia catechu),* Shisham(*Dalbergia sissoo),* Kachnar(*Bauhinia*), *Robinia,* Ban/Oak(*Quercus leucotrichophora)* , Bamboo, Willow(*Salix*), Walnut*(Juglans regia),* Amla(*Phyllanthus emblica), Jatropha,* Ritha(*Sapindus* sp), Daroo ( ), Drake(*Ulmus* sp.), Poplar(*Populus sp*), *Leucaena sp*.	*Quercus species, Rhododendron arboreum, Cedrus deodara* *Pinus roxburghii, Rhododendron campanulatum, Juglans regia* *Phyllanthus emblica, Betula utilis* *Taxus wallichiana, Pinus longifolia*

***https://growbilliontrees.com/pages/tree-plantation-in-uttarakhand-state?srsltid=AfmBOoqt4t-UZzUXESx4DR8MYdB4hJ9luHIrhl-pAiHpJc_ogZxGHhst**
*http://www.wmduk.gov.in/ManualsUDWDP/TM/Forestry.pdf

We have greater risk in Himalayan region linked to impairment of hydrological cycle. Soil loss through overland flow from the degraded hill slopes is more than three times from that of the forested slopes (Pandey et al. 1983). Eroding power of the monsoon rainfall for these catchments are mainly sub-surface flow systems as rainwater is transmitted laterally to the channels via a sub-surface "quick-flow" process (Singh et al. 1983) making the shallow soil highly vulnerable to landslips and landslides .The removal of tree cover causes rapid soil saturation. The forested soil works as sponge for holding the rainwater. The rate of erosion in catchments of rivers has increased five times compared to that in the geological past (Valdiya, 1985).

Oak vs Pine in the Central Himalaya

The rapid deforestation and conversion of forests to cropland in the Central Himalaya have led to severe ecological consequences, including landslides and destruction of human settlements (Tolba, 1977; Valdiya, 1985; Khanka, 1985). This soil displacement accelerates sediment deposition in rivers, leading to recurrent floods in the Indo-Gangetic plains, affecting around 15 million hectares and nearly one-third of India's population (Valdiya, 1985). Additionally, the disappearance of springs and streams—once associated with mesic oak-dominated forests—has contributed to biodiversity loss in this global hotspot. A robust policy framework is urgently needed to halt deforestation and promote ecological restoration. The IUCN (2017) notes that colonial-era policies prioritized fast-growing pine over native broadleaf species, undermining traditional forest-based livelihoods. Pine forests, rich in flammable resins, are highly susceptible to forest fires, which destroy fodder-rich understory vegetation, disrupt forest structure, and threaten lives and property. Moreover, pine plantations worsen water scarcity in hill regions, as pine needles alter soil chemistry and inhibit water infiltration. These monocultures encourage selective grazing, tipping ecological succession in favor of *Pinus roxburghii* over ecologically beneficial species like *Quercus lanuginosa*. Upadhyay and Singh (1985, 1989) found that *P. roxburghii* has a higher C:N ratio (70.67) and lignin content (23.42%) compared to *Q. lanuginosa* (35.50 and 16.96%, respectively), affecting nitrogen cycling and the growth of understory species.

For decades, tree plantation programs in the Central Himalaya have introduced exotic or unpalatable species (Table 4), displacing native oak forests and pastures. This has led to a decline in fodder resources and disrupted traditional pastoralist systems like those of the Gaddis (Sharma, 2021). The expansion of pine plantations has also facilitated the spread of invasive shrubs such as *Lantana camara*, which further degrade local pastures and threaten livestock health (Ramprasad et al., 2020). Although there is now a renewed focus on planting native broad-leaved trees, the role of native shrubs, herbs, and meadow species remains largely overlooked. Lessons from urban greening programs, such as Green Toronto, could be adopted in the Himalayas by incorporating multilayered vegetation types in reforestation efforts. To ensure successful and sustainable plantations, the Miyawaki method—focused on creating native forest ecosystems—should be adopted (Upadhyay, 2011, 2012; Upadhyay et al., 2020). Scientifically validated ecological methods can help identify potential natural vegetation types suitable for restoration (Upadhyay et al., 2010, 2014; Upadhyay and Debata, 2020). Native species lists (Tables 5, 6) reveal striking similarities between the Himalayan and Canadian vegetation, indicating the adaptability of certain genera across continents (Table 3).

Urban forest ecosystems comprising trees, shrubs, meadows, and ground vegetation offer numerous ecosystem services, including air purification, noise reduction, runoff mitigation, and recreational spaces (Escobedo et al., 2011; Gomez-Baggethun et al., 2013; Gratani & Varone, 2005, 2013). Evergreen species offer year-round CO_2 sequestration, especially valuable during high-emission months (Gratani, 2020; Gratani & Bonito, 2016). Long-term research on functional traits of tree species under climate variability is essential for informed species selection (Nowak, 1996, 2010; Myeong et al., 2006; Peters & McFadden, 2012).

Table 5. A list of major forest species of Indian Central Himalayan region (Sangry et al 2024; Thakar et al 2024; Kharkwal et al 2024 ; Rawal et al.2018).

Trees		
Bauhinia variegata Linn.	*Quercus floribunda Rehde*	*Bauhinia vahlii Wight & Arn.*
Cedrela ciliata Roem.	*Euphorbia royleana Boiss*	*Syzygium cumini (L.) Skeels*
Cedrus deodara	*Abies spectabilis*	*Juniperus semiglobosa*
Celtis eriocarpa Decaisne	*Pyrus pashia*	*Grewia subinaequalis DC*
Cornus oblonga	*Rhamnus triqueter Wall.*	*Quercus leucotrichophora.*
Myrica esculenta	*Engelhardtia spicata*	*Cocculus laurifolius*
Parthenocissus semicordata Wall.	*Lyonia ovalifolia*	*Millettia auriculata*
Persea odoratissima	*Pinus roxburghii Sarg*	*Sapium insigne*
Quercus lanuginosa	*Bauhinia retusa Buch-*	*Lonicera quinquelocularis*
Quercus semecarpifolia	*Abies pindrow*	*Pinus wallichiana*
R. campanulatum	*Taxus wallichiana,*	*Acer accuminatum*
Symplocos chinensi	*Acer oblongum Wall, ex DC.*	*Pistacia integerrima Stewart*
Viburnum cotinifolium	*Rhododendron arboreum Smith*	*Murraya paniculata (L.) Jack*
Sorbus microphylla		
Shrubs/saplings /seedlings		
Smilax aspera Linn.	*Lantana camara Linn.*	*Cocculus laurifolius DC*
Smilax vaginata Decaisne	*Acer oblongum*	*Cornus oblonga*
Symplocos chinensis (Lour)	*Adina cordifolia (Roxb.)*	*Cupressus torulosa D. Don.*
Viburnum cotinifolium D. Don.	*Aechmanthera tomentosa Nees.*	*Daphne cannabina Sensu*
Wikstroemia canescens Meissn	*Arundinaria falcata Nees.*	*Engelhardtia spicata*
Lonicera quinquilocularis	*Berberis asiatica*	*Euphorbia royleana*
Murraya koenigii (L.) Spreng.	*BerberIs lycium*	*Indigofera gerardiana Wall, ex*
Myrsine africana Linn.	*Boenninghausenia albiflora*	*Pyrus pashia Buch-Ham ex D.*
Myrsine semiserrata Wall.	*Cassia floribunda Car*	*Rosa brunonii Lindl.*
Parthenocissus semicordata	*Cedrus deodara (Roxb. e*	*Rubus ellipticus Smith*

Persea odoratissima	*Celtis eriocarpa*	*Sapium insigne*
Pyracantha crenulata (D. Don)	*Sarcococca hookeriana Baill.*	
Ground flora/Herbs/grasses		
Vallisneria wallichiana L.	*Viola canascens Violaceae*	*Vitis himalayana Brandis*
Agrimonia pilosa Rosaceae	*Cynoglossum lanceolatum*	*Paspalum spp. Poaceae*
Ainsliaea aptera DC Asteraceae	*Cassia mimosoides*	*Pimpenella spp. Apiaceae*
Ajuga parviflora Lamiaceae	*Crotalaria sessiliflora Fabaceae*	*Platystemma violoides*
Celtis eriocarpa	*Athyrium schimperi*	*Plectranthus japonicus*
Artimesia nilagarica Asteraceae	*Begonia picta Begoniaceae*	*Polycarpa corymba*
Anaphalis contorta Asteraceae	*Conyza japonica Asteraceae*	*Polygonum hygropiper*
Anaphalis margaritacea L.	*E. bonariensis Asteraceae*	*Polygonum nepalense Meisn.*
Bidens biternata Asteraceae	*Erigeron bellidiodes L.*	*Pouzolzia hirta Utricaceae*
Commelina benghalensis	*Erigeron karvinskianus*	*Roscecea procera Zingeberaceae*
Apluda mutica L. Poaceae	*Flemingia bracteata Fabaceae*	*Roscocea purpurea Sm.*
Artemisia annua Linn.	*Galium rotundifolium Rubiaceae*	*Sapium insigne*
Calamintha umbrosum	*Galium. aparina Rubiaceae*	*Satyrium nepalensis Orchidaceae*
Bidens pilosa Asteraceae	*Geranium ocellatum*	*Scutelaria lateriflora L.*
Cocculus laurifolius	*Gerbera gossypina Asteraceae*	*Scutellaria angulosa Lamiaceae*
Bupleurum tenue Apiaceae	*Hedychium spicatum Sm.*	*Sedum sinuatum Crassulaceae*
Carpesium cernuum Asteraceae	*Justicia simplex Acanthaceae*	*Seigesbeckia orientalis*
Dryopteris cochleata D. Don	*Lepidium virginianum*	*Setaria glauca Poaceae*
Carum anathifolium Apiaceae	*Leucas lanata Lamiaceae*	*Setaria homonyma Poaceae*
Campanula colorata	*Lindenbergia indica*	*Stachys sericea Lamiaceae*
Carex nubigena Cyperaceae	*Micromeria biflora Lamiaceae*	*Swertia tetragona Gentianaceae*
Arthraxon prionodes Poaceae	*Neanotis calycina Rubiaceae*	*Synotis penninervis DC*
Centella asiatica Apiaceae	*Nervillea crispata Orchidaceae*	*Teucrium royleanum Lamiaceae*
Ageratum houstonianum	*Onychium cryptogrammoidesH.*	*Thalictrium foliolosum*
Carex. condensata Cyperaceae	*Origanum vulgare Lamiaceae*	*Torenia cordiflora*
Oxalis corniculata Oxalidaceae	*Urena lobata Malvaceae*	

Table 6. Different herb species in moderate to highly disturbed sites in Central Himalayan Forests

Herb species of Himalayan region		
1. *Achyranthes bidentata* 2. *Ainsliaea aptera* 3. *Androsace lanuginose* 4. *Artemisia annua* 5. *Arthraxon lanceolatus* 6. *Bidens pilosa* 7. *Clematis buchaniana* 8. *Craniotome versicolor* 9. *Cynodon dactylon* 10. *Cyperus rotundus* 11. *Galium aparina* 12. *Galium rotundifolium*	13. *Dicliptera bupleuroides* 14. *Dioscorea deltoidea* 15. *Erigeron billidioides* 16. *Eupatorium adenophorum* 17. *Fragaria vesca* 18. *Geranium nepalense* 19. *Gerbera gossypina* 20. *Goldfussia dalhousiana* 21. *Hedychium spicatum* 22. *Justicia simplex* 23. *Lepidagathis cristata* 24. *Melaxia acuminata* 25. *Micromeria biflora*	26. *Onychium cryptogrammoides* 27. *Rubia cordifolia* 28. *Selaginella bryopteris* 29. *Stellaria media* 30. *Thalictrum foliolosum* 31. *Tragopogon gracile* 32. *Tridax procumbens* 33. *Viola canescens* 34. *Viola serpens* 35. *Vitis himalyana*

Suggestions and Recommendations

Urban plantation programs in Canada, especially in cities like Vaughan and Toronto, generally adhere to ecological principles, particularly in species selection, organic enrichment, and aftercare. Observations indicate that coniferous species such as pines and spruces perform well in these climates, showing greater girth increment compared to broad-leaved species. Based on this, several enhancements to the existing Green Toronto planting protocol are suggested:

Avoid Dyed Mulch Materials: Dyed mulch mats used in planting areas may be redundant where organic wood mulch is already present. These mats often lack full organic composition and may not significantly aid in seedling establishment.

Adopt the Miyawaki Method: This successful eco-restoration technique involves adding a 30 cm topsoil layer across the planting site and covering the entire area—not just around the seedlings—with organic mulch or straw. This practice effectively suppresses weed growth, conserves moisture, and improves overall seedling growth and establishment.

Prefer Broadleaf Mulch over Conifer Mulch: Mulch from conifer species like pine and spruce has limited nutrient content. In contrast, mulch derived from broad-leaved species supports faster seedling growth by enhancing nutrient availability in the soil.

Balance Between Evergreen and Deciduous Trees: While the Vaughan program favors deciduous broad-leaved species for their aesthetic appeal in autumn, this limits photosynthetic activity during late fall and winter. Integrating evergreen species, particularly broad-leaved evergreens, can provide ecological benefits year-round while maintaining visual appeal. Though evergreen broadleaf options are limited, conifers can supplement them effectively.

Introduce Herbaceous and Shrubby Ground cover: Cultivating non-competing seasonal herbs and shrubs as ground cover can function as "living mulch." These plants decompose quickly, releasing nutrients into the soil, thereby enhancing soil health and contributing to ecosystem sustainability.

Promote Native Species Tolerant to Salinity: Research should focus on identifying and planting salt-tolerant native species to boost biodiversity in urban landscapes. The organic litter (leaves and twigs) can help reduce soil salinity and enhance overall ecosystem function. In contrast, plantation practices in the Indian Central Himalayan region often overlook ecological principles in species selection, organic management, and aftercare. This has led to poor plantation success, dominance of exotic species, and declining regenerative capacity of native flora. Prioritizing native tree species in reforestation efforts is vital for ecological recovery and climate resilience. Air pollution due to paddy stubble burning in northern Indian states (Punjab, Haryana, NCR regions) remains a critical issue, impacting the air quality of the capital region (PIB, 2024). Though initiatives like pelletization, torrefaction, co-firing with coal, and bio-decomposers have been introduced, their success has been limited. Incorporating paddy straw as mulch within the Miyawaki method offers a practical solution—suppressing weeds, conserving soil moisture, and enriching the soil, thereby enhancing seedling survival and growth.

The plantation strategy must include diverse vegetation—trees, shrubs, and herbaceous species—to mimic natural ecosystems, as practiced in Toronto. Given the similarity in tree genera across both regions, methods from Toronto and Vaughan are applicable in the Himalayas. Wood mulch can be sourced from sawmill sawdust, turning waste into a resource. Engaging trained volunteers can boost plantation efforts. A long-term monitoring network should be established to evaluate plantation success and improve ecological outcomes.

Acknowledgements

I am grateful to Deputy Mayor Ms. Linda Jackson, City of Vaughan, Canada for a very prompt response to make possible my discussion with her officials and also arranging a site visit of city urban forestry/plantation areas in Vaughan. The support from Mr Piragal Thiru, Loui Kakaralis of Forestry and Horticulture Operations, City of Vaughan, Ontario. and Rosalyn Endlich, Natural Environment Specialist, Natural Environment and Community Programs, City of Toronto is gratefully acknowledged.

References:

Crawford Bruce and Raul Cabrera (2021). Tree, Shrub, and Flower Growing Publications. Cooperative Extension Fact Sheet FS099. Problems With Over-Mulching Trees and Shrubs. *New Jersey Agricultural Experiment Station, USA.*

Gohring Ken (2021). Mulch Basics and Beyond.The Azalean. *Winter* 2015. 37(4):83

Gratani L (2020) Understanding the Benefits from Green Areas in Rome: The Role of Evergreen and Deciduous Species in Carbon Dioxide Sequestration Capability. *American Journal of Plant Sciences,* 11, 1307-1318..

Escobedo FJ, Kroeger T and Wagner JE (2011) Urban Forests and Pollution Mitigation: Analyzing Ecosystem Services and Disservices.*Environmental Pollution*, 159, 2078-2087.

Gomez-Baggethun E, Gren Å, Barton DN,et al. (2013) Urban Ecosystem Services. In: Elmqvist, T., Fragkias, M., Goodness, J.,et al., Eds.,Urbanization,Biodiversity and Ecosystem Services:Challenges and Opportunities, Springer, Dordrecht, 175-251.

Gratani L and Varone L (2013) Carbon Sequestration and Noise Attenuation Provided by Hedges in Rome: The Contribution of Hedge Traits in Decreasing Pollution Levels. *Atmospheric Pollution Research*, 4, 315-322.

Gratani L and Varone L (2005) Daily and Seasonal Variation of CO 2 in the City of Rome in Relationship with the Traffic Volume.*Atmospheric Environment,* 39,2619-2624.

Green Directions (2019). City of Vaughan:2019Community Sustainability Plan. In: City of Vaughan-Environmental Sustainability 2141 Major Mackenzie Dr. Vaughan, ON, Canada L6A 1T1 (vaughan.ca).

http://www.wmduk.gov.in/ManualsUDWDP/TM/Forestry.pdf

https://growbilliontrees.com/pages/tree-plantation-in-uttarakhand-state?srsltid=AfmBOoqt4t-UZzUXESx4DR8MYdB4hJ9luHIrhl-pAiHpJc_ogZxGHhst

https://networkofnature.org/userContent/documents/Local%20Species%20Lists/Recommended%20Native%20Species%20List%20-%20BC%20Nature.pdf

ITTO (2002). Tropical timber products; Development of further processing in ITTO producer countries. ITTO Geneva 2002

IUCN,2017.Blog:Restoring forests for the future of Himalayan Mountain communities. https://iucn.org/news/asia/201707/blog-restoring-forests-future-himalayan-mountain-communities

Kant Promode and Raman Nautiyal (2021). India Timber Supply and Demand 2010–2030, ITTO. www.itto.int/other_technical_reports.

Khanka S S (1985). Labour migration and its effects in a low developed region of Uttar Pradesh. Pages 196–213in J. S. Singh (ed.), Environmental regeneration in Himalaya: Concepts and strategies. Central Himalayan Environment Association, Gyanodaya Prakashan Nainital, India.

Kharkwal G K, P Mehrotra,Y S Rawat and Y P S Pangtey. (2004). Comparative Study Of Herb Layer Diversityin Pine Forest Stands At Different Altitudes Of Central Himalaya. *Applied Ecology And Environmental Research* 2(2): 15-24.

Larum Darcy (2023). Is Colored Mulch Toxic – Safety Of Dyed Mulch In The Garden. August 2, 2023. https://www.gardeningknowhow.com/garden-how-to/mulch/dyed-mulch-in-gardens.htm .

Gratani L and Varone L (2006) Carbon Sequestration by Quercus ilex L. and Quercus pubescens Willd. and Their Contribution to Decreasing Air Temperature in Rome. *Urban Ecosystems*, 9, 27-37.

Nowak DJ, Rowntree RA, Mcpherson EG, Sisinni SM, Kerkmann ER and Stevens JC (1996) Measuring and Analyzing Urban Tree Cover.*Landscape and Urban Planning,* 36, 49-57.

Myeong S, Nowak DJ and Duggin MJ (2006) A Temporal Analysis of Urban Forest Carbon Storage Using Remote Sensing. *Remote Sensing of Environment*, 101, 277-282.

Nowak DJ (2010) Urban Biodiversity and Climate Change. In: Muller, N., Werner, P. and Kelcey, J.G., Eds.,Urban Biodiversity and Design, Wiley-Blackwell Publishing, Hoboken, New Jersey, 101-117.

Peters EB and McFadden JP (2012) Continuous Measurements of Net CO 2 Exchange by Vegetation and Soils in a Suburban Landscape.*Journal of Geophysical Research-Biogeosciences*, 117, 1-16.

OPR (2022)). City of Vaughan Official Plan Review: Urban Design, Built Form,Compatibility, and Sustainable Development Criteria Review . Background Paper August 2022

PIB (2024). Parliament Question: Air Pollution caused by Stubble Burning Ministry of Environment, Forest and Climate Change, Posted On: 25 NOV 2024 5:20PM by PIB Delhi India

Ramprasad V, A Joglekar and F Fleischman (2020). Plantations and pastoralists: afforestation activities make pastoralists in the Indian Himalaya vulnerable. *Ecology and Society* 25(4):1.

Rawal S Ranbeer Renu Rawal, Balwant Rawat, Vikram S. Negi & Ravi Pathak (2018). Plant Species Diversity and Rarity Patterns Along Altitude Range Covering Tree line Ecotone in Uttarakhand: Conservation Implications. *Tropical Ecology* 59(2): 225–239, 2018

Ros–Tonen, Mirjam, Wim Dijkman and Erik Lammerts Van Bueren, (1995). Commercial and sustainable extraction of Non Timber Forest Products : Towards a policy and management oriented Research Strategy. Tropenbos Foundation, Wageningen, The Netherlands. 32p.

Sangry S, Kumar P, Bhardwaj DR, Dogra KS and Poonam (2024) Abundance, diversity and composition of understory plants along the altitudinal gradient and dominant overstory composition types in the temperate Himalayan region. Front. For. Glob. Change 7:1420855. doi: 10.3389/ffgc.2024.1420855

Sharma Seema (2021). Tree planting pushes out pastoralists in the Himalayas. Dialogue Earth. 15 Printing House Yard, Perseverance Works, London, E2 7PR

Smith WH (1981) Air Pollution and Forests Interactions between Air Contaminants and Forest Ecosystems. Spnnger-Verlag New York

Thakar Anil, Deeksha Dave and Sagar Singh (2024). Diversity, Spatial Distribution and Biomass Patterns in Oak and Pine Forest Community along Altitudinal Gradient in Paddar Range of Kishtwar Forest Division, Northwestern Himalaya. Indian Journal of Ecology (2024) 51(4): 738-743(DOI:

Tolba MK (1977). Development without destruction. *Agriculture and Environment* Volume 3, Issue 4, , Pages 369-379

Upadhyay V P (2012). Eco-restoration technology for lands degraded due to opencast Chromite and Iron ore mining in Odisha. In: Souvenir, 4th Ramdeo Misra memorial centenary lecture. National Institute of Ecology and Orissa Environment Society, Bhubaneswar

Upadhyay V P, RK Mishra, Shahida P. Quazi and V.Saio (2020). Research needs for sustainable productivity in mining and mineral based industries in Odisha, India. ARWM 5(3): 1-12

Upadhyay V P, T Yagasaki and S Okuda (2014). Application of quantitative approach on the analysis of oak-mixed forests in India and Japan. *Plant Science Research* 36 (1&2): 34-42.

Upadhyay VP (2011). Reclamation of degraded mining lands in eastern region of India: An action plan. Prakruti Vikas 15-20 (March, 2011).

Upadhyay VP and A Debata (2020). Biodiversity assessment in EIA: A Guidebook. State ENVIS Hub, CES, Forest and Environment Department, Odisha. 70p.

Upadhyay VP AND JS Singh (1989). Nitrogen Release Pattern in Decomposing Oak and Pine Litter in Nainital Hills India. *The Indian Foreste*r 115(5): 320-326.

Upadhyay VP, Aigul K. Akhmetovva and T Yagasaki (2010). Phytosociological study of vegetation of Shikinomori Park protected Forests. Project report (J 1004188) JICA, Yokohama International Centre, Yocohama, Japan-230001 42p.

Valdiya KS (1985). Accelerated erosion and landslide-prone zones in the Himalayan region. In Singh, J.S.,ed., Environmental Research in Himalaya: Central Himalayan Environmental Association, Nainital, p. 39–53.

WMD (2014). Manual of Forestry. Uttarakhand Decentralized Watershed Development II Project (GRAMYA II), Watershed Management Directorate Dehradun (www.gramya.in).