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Pine trees and their contribution to climate change in the Western Himalayas

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Executive summary

The Himalayan Mountains attract tourists and explorers from all over the world. Thousands of people come every year to visit and spend time in the small hill stations located in the large area of the Himalayas. But the Himalayan ecosystem is a particularly fragile one, considering the array of natural calamities occurring around the region. One sees a sizable area of coniferous pine trees monoculture when one enters into the Himalayas. They are long, perfect, often described as beautiful and are recognized for their ornamental beauty. But this beauty has been costing Uttarakhand, Himachal Pradesh, Meghalaya and other places within the Shiwalik and Himachal ranges of the Himalayas a lot in the last couple of centuries. There is a fiery debate on the utility of pine trees within forest officials and scientists. Pine is a dominant tree species that spreads in the forest, and is often blamed for not allowing undergrowth, a primary source of forest fires and diminishing water levels in the pine dominated areas. According to some foresters, forests are becoming overpopulated with pine tree species that do not yield anything suitable for fauna like monkeys, elephants, or even livestock, that wander into human habitat in search of food. Through this paper we shall focus on the

- Woes pine trees have on the Indian Himalayan environment, especially in the state of Uttarakhand
- How Chir pine forests are contributing to climate change
- Suggest ideas to address and mitigate their effects.

Introduction

Reports suggest that climate change would increase the average air surface temperatures by several degrees (+1.8°C to +4°C) in this century. This rise in global temperature has an influence on the Himalayan region, causing more frequent flooding, landslides, and other natural disasters. Air temperatures have risen by nearly over one degree Celsius across the high mountain region, which runs from Afghanistan in the west to Myanmar in the east, since the turn of the century—and the chilly temperatures have warmed up quicker than the rest of the world. As a result, glaciers are receding, permafrost is melting, and weather patterns are becoming more irregular, interrupting formerly reliable water sources and causing more natural disasters. Without coordinated worldwide measures to reduce greenhouse gas emissions, the figures could rise much higher. If present emissions trends continue, research suggests, warming across the Indian subcontinent might range from 2.1 to 2.6°C in the 2050s to 3.3 to 3.8°C in the 2080s. And if emissions continue to climb, that amount might rise to more than 6°C. Farmers cultivating apples or grains on steep mountain slopes must shove their orchards higher upslope to

get the cool nights and seasons required by their crops. For others, shifting snow and rain patterns caused the once dependable streams and springs to become dry, or unsafe, with the potential of deadly floods.

Pinus Roxiburghii, locally known as Chir pine or longleaf Indian pine is an Indian species of pine tree which is vastly common in the Himalayas. They are found at altitudes between 600-2300m. They are an evergreen, coniferous species of flora that can grow up to heights of 55m (180 feet) with trunk spanning over 100 cm (60 inches) in diameter when fully matured. They have important usage for timber generation, resin production and also ayurvedic utilities. Chir pine trees are very well adapted to dry and high-altitude environments and can grow on a variety of soil types like well-drained gravelly loamy soil and also on calcareous soil. They have a lifespan of 40-50 years and can reach maturity by 20-30 years of age. A light, well-drained, sandy, or gravelly loamy soil is ideal for the plant's growth. It tolerates calcareous soils well and dislikes moorland soils with poor drainage. As Chir pines increase the acidity of the soil through their fallen needles, they typically do not allow any vegetation to grow around them. Chir pines are mostly endemic to Myanmar, Nepal, Bhutan, Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh. Through Pakistan, it can also be found in Tibet and Afghanistan.

The nature of Pine trees are highly debated for if they are a native species in India and can be mostly regarded as a harmful species in the Himalayas, as they bring along many woes such as making the soil dry, acidic, and non-suitable for vegetation of other species of plants. They also have exceptionally low water retention capacity, which affects the region's water levels. Their dry nature also contributes to forest fires and its circulation in the forests. They also pollinate very quickly and effectively resulting in diminution of scope for other species of native flora such as oak to grow. Present government policies and laws also oblige us to preserve the pine trees in India which is contributing to promoting the monoculture of pines in the Himalayas.

Keeping in mind that over a quarter of forest cover in Indian Himalayas are dominated by pine trees (primarily Chir pine), there has to be effective measures to promote and increase the population of native evergreen and deciduous trees such as Teak, Sal, Deodar, Oak as their numbers have significantly reduced due to having lighter legal regulation for their protection and also the unprecedented growth and takeover of pine trees in the Himalayas, creating a dominating and alarming monoculture of nothing but Chir pine trees. Oak trees are native, resourceful and have been abundant in India during pre-colonial time, but human exploitation and natural replacement has significantly reduced their numbers, along with the environmental and social benefits that Oak trees bring along with them. But the ban on cutting pine trees has led to over exploitation of Oak trees, and over population of the merely resourceful Chir pine trees. The reduction in the variety of biodiversity is affecting the ecosystem and that in turn would compromise

the environmental, social and physical well-being of the native humans and animals of the Himalayan regions.

Literature review

The Himalayan Mountain range is home to the world's highest peaks, such as Mount Everest and K2. It covers a vast area of South Asia, spanning five countries and providing a unique ecosystem for a variety of flora and fauna. In India, the Himalayans span across the northern region, covering states such as Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Sikkim and the state of Northeastern India. The range has a rich history dating back to millions of years ago, with its formation beginning during the Mesozoic era. It has a significant impact on our country's climate, natural resources, culture and also has been a subject of exploration and study for geologists, botanists and many other scientific domains for centuries. The range, being one of the biodiversity hotspots of the world, consists of a range of native species of flora and fauna. But the biodiversity equilibrium has been significantly affected and altered since the inception of the British in India, introducing exotic species which have taken over the native habitat posing hazards to the fragile ecosystem of the sedimentary young-fold mountains of the Himalayan range.

The story of Chir pine trees in India

Colonialism and commercialization had disastrous effects on Himalayan stability. One such species is the species of Pinus Roxiburghii or locally known as Chir pines, growing in the outer Himalayas and the Shiwalik ranges, with its first appearance ever on the Shiwalik ranges which were planted stocks and not natural ones. Although Chir pine exploitation which led to its increasing population was supported by the British, there are reports that Chir pine trees date back over many centuries, which were at lesser quantity. On the Mussoorie and Nagtibba chain, deciduous trees were first replaced by Chir Pine trees. These forests extend to the Bhagirathi Ganga Valley where Chir pines almost reach the riverbed and upwards to the northern exposed slopes of Udara and Bhuki where evergreen and coniferous mixed forests can be seen. It is estimated that the coniferous species planted so far in the Himalayas extend to about 20,000 hectares. Exotic trees species such as eucalyptus, pine, Japanese cedar are fast-growing and have contributed to the reduction of native forest cover and also hampered many ecosystem services such as water retention. Among conifers, pine trees, specifically Chir pine trees occupy a major area in the mountains.

It is observed that different regions of the Himalayan forests have seen intense biodegradation in the past century, human exploitation on the native Oak ecosystem has been extreme. While the Oak forests and

zones of human settlements broadly overlap, it is regrettable to see the prevailing forest practices show a sharp bias against the oak forest. During the pre-British era before 1816, the populaces of the Himalayas were low and oak and other forests were ample to sustainably support the agro-forestry practices and meet construction demands such as mining and iron smelting. Oak trees are regarded as the best-friends of the people living in the Himalayas as the trees absorb water for a long time and releases the same slowly, maintaining the water springs in the region. Its leaves can be used as fodder, with a leafy canopy and rich undergrowth of grasses, protecting the soil below from directly being hit by rain and its wood having manufacturing implements.

When agricultural activities in the Himalayas accelerated after the inception of the British (1816) for revenue generation, Sal trees were the first to be largely overexploited. Back then, organized forestry had not been conceived, resulting in an unrestrained exploitation. The emergence of the railway era along with the military demand for the two following World wars further led to Sal overexploitation. When the number of Sal trees diminished due to its exploitation, Deodar tree exploitation began to meet the requirements of manufacturing railway sleepers. Chir pine tree exploitation did not begin until the early 20^{th} century, when technology improved for resin tapping from the pine trees. Resin tapping became an important source of revenue generation since 1911 and its yield gained special importance since the fast-growing exotic pine trees of as low as just 25 cm diameter at breast height (dbh) were allowed to be tapped for increasing yield and revenue. It is said that the British used to scatter Chir pine seeds from helicopters into the forests of Uttarakhand to increase its population for yield and revenue. The post-colonial period also saw the same exploitation towards the pines as the government still hailed the colonialist legacy of generating revenue. Below is table 2 indicating the increase in the population density of Chir pine in 20 predominantly pine forest compartments selected at random, comparing changes from a base year up to 1978.

Table 1- Increase in the population density of Pinus roxburgii (Chir pine) in 20 predominantly pines forest compartments selected at random. Density values are in stems >10 cm diameter per ha. (Singh, 1991)

Compartment number and block	Density in base year	Density in 1978
1, Gagar*	16.0	234.4
3, Gagar*	0.6	113.1
4, Gagar*	10.0	86.6
6, Gagar*	24.3	102.8
10, Gagar**	59.1	226.5

11b, Gagar**	61.6	165.4
6a, Jangliya*	24.6	189.4
6a, Lohakhan*	11.0	134.2
8a, Lohakhan*	9.0	187.9
10b, Jakh***	26.1	149.3
13a, Patlot***	127.7	279.2
14, Patlot***	53.2	161.2
6, Raikuna*	22.7	189.1
3a, Bhowali**	77.8	160.8
5, Bhowali*	21.4	253.0
10b, Bhowali**	21.8	129.2
11, Bhowali*	46.6	65.8
2a, Dolmar**	22.4	56.8
26, Garnath**	11.9	196.0
31, Sukhatal**	14.9	341.9

**Base year 1927, **Base year1952, ***Base year 1938*

The silvicultural practices to rejuvenate Sal and Deodar could not be implemented adequately, as they were late successional species, and early successional species such as Chir pines regenerated easily. It is regarded that pine encroaches oak forest from the hill bases to ridge tops making Chir pines abundant in the Himalayas. The easy and early pollination of the pine tree seeds as compared to other native species contributes to its overpopulated monoculture. When an area is invaded by pines, it prevents the possibility of reinvasion of oak trees in the area due to certain characteristics of the pine trees. This man-made forest of pine trees is not capable of maintaining the ecological balance the same way natural forests do. Table 2 below portrays the lion share of forest cover pine trees dominate in the Indian region of the Himalayas.

Table 1- Forest cover under different forest types (1991) (Sinha, 2001)

Forest types	Area (*000ha)	Percentage in total
Subtropical broad leaved hill forest	287	2.72
Subtropical pine forest	**3740**	**35.43**
Subtropical dry evergreen forest + Sub-alpine forest	173	1.64
Montane wet temperate forest	1613	15.28
Himalayan wet temperate forest	2725	25.82

Himalayan dry temperate forest	227	2.15
Moist alpine forest	1790	16.96
Total	10555	

Monoculture of Chir pine trees in the Himalayas is still rampant. If the trend continues, the future of the Himalayan Mountains would be suffocated with pine trees and there would be total impoverishment of the environment.

Benefits and uses of Chir Pine trees

Chir wood is used for a variety of things, including the building industry and the manufacture of panel goods. A crucial oleo-resin that is produced by Chir pine trees is used as a raw ingredient in the rosin and turpentine oil industries. Chir needles produce an essential oil and are ideal for making needle boards. Its bark can be used to produce tannin that is appropriate for curing leather, and its seeds are a good source of fatty oil.

Chir Pine offers a wide range of products and services to the public. In actuality, every part of the tree has value and is utilised in some way. It is a common timber in North India, especially in the hills, and is used for a variety of things, such as building houses, rafters, poles and posts, doors and windows, roof shingles, flooring blocks, packing boxes, boards, railway sleepers and the production of pulp and paper. It is also used to make flooring blocks and flooring boards. It is appropriate for making boats, tea chests, sporting goods, violin bodies, matchsticks, oars, and other items.

Various uses of the Chir pine tree are given hereunder:

- Construction-

  Chir pine wood has been classified under ordinary group for structural use in construction of buildings and is suitable for nailed and bolted timber construction. The wood is least preferred for local building purposes due to its nature of being most prone to decay but is still used due to lack of alternative timber sources in the pine growing altitudes.

- Railway sleepers-

  Chir pine wood was considered useful for the construction of wooden sleepers for railway tracks. The finished sleepers have a life of about 17 years.

- Furniture and architectural use-

  Chir pine wood is used to manufacture door/windows/shutters and ventilator frames in houses/buildings. They are also used to produce furniture, as they have a strength coefficient of over 50.

- Packing cases and crates-

  Having features such as its light colour, moderate weight, and nail/screw holding capacity, Chir is one of the conifer species most frequently used in the production of packing cases and crates. For packing apples and other horticultural produce, boxes made of Chir wood are just as effective as those made of other common woods. Chir pine can also be used to make plywood tea chest battens.

- Miscellaneous uses-

  Single solid logs of Chir pine tree are used as wooden poles for overhead power and telecommunication lines. They are also used for making fence posts, dunnage pallets, cross-arms and cable drums.

- Pulp and paper making-

  Chir pine contains long fibres that are 0.052 mm in diameter and 3.6 mm in length on average. It has the highest tear and burst factor among the species used to make paper, yielding 40–43.5 percent of bleached grade pulp with satisfactory strength qualities. The printing paper created entirely from Chir pine pulp has good forming and acceptable strength properties.
  The species is also appropriate for producing paper used as electrical insulation. The leftover wood from industries and sawmills is highly suited for making white writing and printing paper in the current supply and demand environment. Twisted Chir, which is virtually ever used for anything else, yields around 53% unbleached pulp, which is utilised to make wrapping paper that is sufficiently dense.

- Resin-

  Chir pine produces high-quality oleo resin that, when stem-distilled, yields two crucial industrial products: turpentine oil (approximately 70%) and rosin (17%). Numerous industries, including soap, paper, paints and varnishes, linoleum, sealing waxes, oil cloth, inks, road construction and disinfectants, use rosin extensively. The creation of paints and varnishes, polishes, chemicals and

medications are the main uses for turpentine. Additionally, it is employed in the home and for the dissolution of resin and lipids. Pine resin essential oil can also be extracted from the resin and used in Aromatherapy for its fresh and woody scent; it has a soothing and relaxing effect on the mind and body.

- Needles, seed and bark-

  Chir pine needles are utilised as bedding material in cowsheds as they provide insulation from the cold ground and also as packing wool in vegetable and fruit boxes. The kernels of the Chir pine tree are rich in fats and proteins and are edible by humans. The barks have tannin content in them upto 14 per cent and hence is used in the leather industry. Its raw barks can also be used in making terra-cotta articles.

- Ayurvedic use-

  Turpentine, typically produced from the bark (20%), pinene, and abietic acid are the main chemical components of Chir pine. The main components of the essential oil made from oleoresin are alpha- and beta-pinene, carene, and longifoline. Chir is essential in the treatment and management of respiratory issues like cough, cold, asthma, osteoarthritis, gastrointestinal problems, skin infections, and other wounds and burns because it contains a variety of bioactive components that have antibacterial, analgesic, anti-inflammatory, antioxidant, astringent, anti-ulcer, digestive, expectorant, hypolipidemic, hepatoprotective, diuretic, and diaphoretic properties.

- Ornamental uses-

  The Chir pine tree is used for ornamental purposes such as Christmas trees and wreaths. Pine boughs are also derived from pine trees as they smell soothing and green and cosmetically beautiful. Also, the endless monoculture of Chir pine trees is a common sight in the Himalayas as they stretch in huge areas and act as a symbol of revival and contributes towards tourism.

- Ecosystem services-

  Besides all the timber and recreational uses provided by pine trees, they also sequester carbon dioxide from the environment and release oxygen for us humans, contributing towards fresher air in the hills. They also provide habitat for many species in the forest as well as contribute towards the green cover of the Himalayas.

Benefits of Oak trees in the Himalayas

It is observed that different regions of the Himalayan forests have seen intense biodegradation in the past century, human exploitation on the native Oak ecosystem has been extreme. While the Oak forests and zones of human settlements broadly overlap, it is regrettable to see the prevailing forest practices show a sharp bias against the oak forest. During the pre-British era before 1816, the populaces of the Himalayas were low and oak and other forests were ample to sustainably support the agro-forestry practices and meet construction demands such as mining and iron smelting. Oaks are an unusual species in a predominantly tropical country like India, but they represent the backbone of the temperate moist forest biome found in the Himalayas between 1,500 and 2,700 meters. Oak trees are regarded as the best-friends of the people living in the Himalayas as the trees absorb water for a long time and release the same slowly. The oak roots continue to take water from deeper layers of soil at night. The *water* is subsequently released into the shallow soil layers by the shallow roots, making water available to shallow-rooted plants. This provides a considerable source of water for plants with shallow roots. The trees' strong, deep root systems have proven to be good at ground stabilisation, moderating water absorption and safeguarding valuable topsoil from erosion. *Soil conservation* and the inclusion of valuable water can reverse the consequences of land degradation, restoring it to a thriving ecosystem. The oak generates a considerable amount of microbial biomass, which includes bacteria and fungi. This releases carbon into the soil, where it accumulates as organic carbon. Over time, the oak population becomes dense within a very limited area, and this, along with the high soil carbon, results in a very high total ecosystem carbon. These factors contribute towards better *carbon sequestion* in the region. Some of the ecosystem goods and services provided by oak and pine forests in the central Himalayas can be found below in the table (Source: Negi, 2022).

Table 3- Ecosystem goods and services provided by Oak and Pine forests in Central Himalayas (Negi, 2022)

Environmental services and goods (ES)	Oak Forest	Pine Forest
Ecosystem Goods		
Fodder	Low-quality, but palatable	Non-palatable
Fuelwood	Good quality	Inferior quality
Seed	Supports wildlife	Edible by human

Medicinal Value	Some	Some
Minor forest products	Many	Few
Small Timber	Rarely used	Frequently used
Agricultural Implications	Good	Hardly used
Resin	No	Yes
Leaf litter as manure	High	Low
Other uses of leaf	None	Roofing/Brooms
Ecosystem Services		
Carbon Sequestration	High	Low
Biodiversity	High	Low
Fire resistance	Low	High
Soil Conservation	High	Low
Water quality regulation	High	Low
Microhabitat for Flora and Fauna	High	Low

From the above table, it can be observed that the economic contribution of Pine Forest outweighs the ecological contribution of Oak forests in the absence of valuation of ES properly. The oak trees do not appear to suffer from any serious pests or diseases. They can grow upto 10-15 meters and age over 200 years. The tree has unlimited value. Its leaves can be used as fodder, with a leafy canopy and rich undergrowth of grasses, protecting the soil below from directly being hit by rain and its wood having manufacturing implements-unlike in Chir pine forests.

Carbon farming, Emissions Trading System (ETS) and Tāmata Hauhā

With the ever growing pollution and GHG emission in India, techniques to tackle the emissions are the need of the hour. Carbon farming associated with ETS is a way that could tackle and address the issue of Chir pine monoculture in India. Carbon farming is a way to remove carbon dioxide from the atmosphere and store it in the soil and vegetation. This can be done through various practices such as planting cover crops, reducing tillage, and managing grazing. The carbon that is stored in the soil and vegetation can help mitigate climate change by reducing the amount of carbon dioxide in the atmosphere. The Ministry of Environment, Forest and Climate Change (MoEFCC) has launched a program in 2021 called the Green India Mission, which aims to increase the country's forest cover and improve soil health. The Mission has

set a target of 10 million hectare on forest and non-forest lands to increase forest/tree cover and improve the quality of existing forest. This program includes initiatives related to carbon farming. Carbon farming could have several benefits in India, such as improving soil health, increasing crop yields, and mitigating climate change. By sequestering carbon in the soil and vegetation, carbon farming can help reduce the amount of carbon dioxide in the atmosphere, which is a major contributor to climate change. Additionally, carbon farming practices can help improve soil health, which can lead to increased crop yields and better water retention.

An Emissions Trading System (ETS) is a cap-and-trade program where a cap is set on the total amount of greenhouse gas emissions that are allowed to be emitted by a certain industry or company. The companies are issued permits to emit a certain amount of greenhouse gases. If a company emits less than its allotted amount, it can sell its unused permits, also known as Carbon Credits to other companies that need more permits. This creates a market for permits and provides an incentive for companies to reduce their overall greenhouse gas emissions by improving technology and functioning efficiently. This norm puts a certain pressure on polluting industries to curb their emission, otherwise having to pay extra per ton of carbon dioxide produced by the industry. India has not implemented a nationwide emissions trading system. However, some state-level initiatives have been taken to curb greenhouse gas emissions. For example, the state of *Gujarat* has implemented a trading system for renewable energy certificates.

Carbon farming can be associated with emissions trading systems by allowing farmers to generate carbon credits that can be sold to companies or governments looking to offset their carbon emissions. These carbon credits represent the amount of carbon that has been sequestered through carbon farming practices, and can be traded on carbon markets as part of an emissions trading system. By creating a financial incentive for carbon farming, emissions trading systems can help encourage the adoption of sustainable farming practices that can help mitigate climate change.

The model of a company called Tāmata Hauhā, based in Māori, New Zealand is an empowering example of how carbon farming with ETS could contribute towards land-development of barren or unfit land along with generating revenue from plantation of trees. The company aims to return to native forestry, from the profits produced by exotic species such as pine trees. They create forestry of exotic species which is well regulated and maintained that could sequester large amounts of carbon whilst also also producing opportunities for diversification as well as habitat and food supply for our fauna. Although exotic plantations could hamper the ecosystem of the region, the regulated and controlled exotic forests could generate drastically higher rates of revenue than from native forests. The start with exotic plantation with the idea to slowly transition towards more native plants, they would see a wider outcome to the region.

They use ETS to help reduce carbon emissions and meet the international targets for climate change in New Zealand by 2050.

The currency they use is New Zealand Emissions Unit (NZU). Each NZU equals one ton of CO2 or its equivalent in other greenhouse gases. NZUs are bought and sold between companies, with emitters paying NZUs based on the amount of carbon dioxide they release. Forest owners can earn NZU's from the government as trees absorb carbon dioxide, removing it from the atmosphere. The foresters can then sell those NZU's to emitters. The price of NZU's depends on a variety of things, but primarily based on supply and demand – how many emission units are available and how much businesses want or need to buy in order to emit. The ETS encourages businesses to search for ways to cut emissions through day-to-day practises and investments in assets and technologies by putting a price on carbon. Such a model would certainly sculpt a sense of responsibility within the citizens to cut their GHG emissions.

Methodology

Statement of Problem

To understand the impact Chir pine trees have on the Indian Himalayan environment, and how they are further contributing to climate change. There is a problem with the growing population of Chir pine trees in the Himalayas, dominating other native species such as Oak. The monoculture of the pine trees without proper policies and mechanisms for its mitigation has affected the Indian Himalayan environment in various ways such as reducing water holding capacity in the soil, causing landslides, forest fires, making the surface warmer and also dominating other forests such as oak.

Aims and Objectives

The primary aim and objective of the study is to highlight the woes Chir pine trees have on the Indian Himalayan ecosystem and suggest ideas to mitigate their effects which are contributing to climate change. Special emphasis has been given to the state of Uttarakhand which has over 28% in Chir pine forest cover. The study seeks to focus on the negative effects that Chir pine trees have on the environment and how their increasing populations in the mountains are hampering the local native flora, fauna and the people up to the present times.

Research Approach

The approach used to formulate the study is the narrative approach. Here, data or facts were gathered from the subjects through interviews, journals and documents over time and is written in a systematic story-like format. This type of approach is based on a theme and the pieces of facts and information are put together in a sequence and in a chronology later, after the data has been collected.

Study Design

- Area of study and details of respondents

  The study was conducted amongst the residents of the Western Himalayas, especially in the state of Uttarakhand which has the highest cover of Chir pine trees in the country. Stakeholders were consulted at the G.B. Pant Institute of Himalayan Environment, Almora and other residents within the periphery of pine forests were consulted.

- Research tool and Technique

  A semi-structured interview was conducted with the stakeholders and residents within the Pine forest in Uttarakhand. Respondents were interviewed telephonically with accordance to the topic of study.

- Data Collection Tool

  For primary data collection, interviews consisting of qualitative questions were used. The researcher first established a basic rapport with the stakeholders followed with topic related questions. The interviews were done at individual level and through virtual means. The interview, which consisted of socio-economic, cultural and environmental aspects of their lives, was gathered for interpretation. The interviews were conducted to know about how Chir pine forest were affecting their lives and the environment, and also to verify the secondary data that had been collected. For secondary data collection, many research papers, journals, and print media were referred to. The secondary data has been appropriately cited in the reference section.

Results

The following results are primarily derived from secondary sources and have been verified with major stakeholders in the subject for the study.

Negative effects of Pine trees on Himalayan environment

The Earth's atmosphere is warming, and the consequences of climate change are becoming clear. The average levels and variability of temperature and precipitation are changing, which is an important observation. Temperature and water availability fluctuations impose multiple environmental restrictions that cause changes at the molecular and forest stand levels. When most people think of the Himalayas, they imagine tall pines encircling the mountains. Few people realise, however, that many of these conifers are forced intrusions that are substantially to blame for the mountains' delicate status. Before the British arrived in India, the Himalayan woods were a verdant canopy of deciduous and evergreen trees, including these conifers. However, in the early nineteenth century, the British used trees such as Oak, Sal, and deodar for commercial purposes, resulting in a significant loss of the native canopy. Due to the failure of the forest ecosystem to recover to its former state, desert-like conditions have now emerged in many parts of the Himalayan region, including Meghalaya, Ladakh, Kumaon, and Garhwal, accompanied with a loss in dense forest cover. Mentioned below are the effects of pine trees in the Himalayas-

- Forest Fires-

  Pine needles which are typically shed during the autumn season, are highly inflammable and are the leading cause of forest fires in the Himalayan region. The Chir pine trees produce a large number of flammable needles and resins, which can ignite easily and spread flames quickly. Also, pine trees are often found in dry, arid environments which are more prone to forest fires. The inflammable carpet of Chir pine needles (leaves) burn in no time spreading the fire quickly to large swathes of the forest. This fire does not spread to the fire-resistant pine tree, which continues to drop leaves the next year, completing the cycle. This annual fire caused by Chir pine trees damage the new sapling that may be sprouting in the forest and also disrupt human and animal that may be in the path of the forest fire. The annual fire also contributes to air pollution as it releases large quantities of carbon dioxide and other greenhouse gases into the atmosphere which further increase in the overall temperature of the Himalayas.

- Lack of Water Retention-

  Chir pine trees can contribute to a lack of water retention in the soil by absorbing large amounts of water through their roots and needles, making the soil and water springs in the region dry and also making the soil prone to erosion. They are trees with high water demand, leading to depletion of groundwater resources and water availability for other plants and animals. The soil's ability to retain water reduces due to a lack of microbes. Unlike areas which have a lot of broadleaf trees like oak which have high water holding capacity, holding up to 40% of the rainwater they receive and contribute to revival of water springs, the Himalayan region with the

pine trees are mostly drought prone. They can carry 8%-16% of the received rainwater resulting in women having to walk sometimes over 10 km to get the water for their normal use.

- No Bacterial Growth, thus no undergrowth-

  A carpet of pine needles covers the forest floor and they do not allow undergrowth of shrubs or bushes due to the acidic nature of the pine needles. Because of the presence of pine, microorganisms in the soil die and are replaced by a parasitic fungal relationship that only helps pine live and expand while depleting resources available for other plants to grow. The dry nature of pine forests needles inhibits the growth of native oak and other plants, contributing to the disruption of the original ecosystem.

- Soil erosion and landslides-

  The pine forests create an environment prone to rainfall runoff generated soil erosion and landslides because the trees' needles and branches create a dense canopy that prevents rainwater from reaching the ground. The pine trees' roots are not deep enough to hold the soil in place, which makes it easier for the soil to erode during heavy rainfall. The soil erosion can lead to landslides because the soil becomes unstable and can no longer support the weight of the trees and other vegetation. This causes the water to run off quickly, taking soil with it and causing erosion. Landslides can be dangerous and can cause a lot of damage to the environment and nearby communities.

- Easy pollination-

  Pine trees pollinate easily because they produce a significant amount of lightweight pollen that may be blown long distances by the wind. Furthermore, pine trees frequently produce both male and female cones on the same tree, allowing for self-pollination and increasing the likelihood of successful fertilisation. New needles emerge between February and March, and old needles fall between May and June. Flowering occurs from February through April. Cones mature in 25 months (about 2 years). They usually open in April or May, but they might open as early as March or as late as June, depending on the weather. 10-12 seeds weigh one gram, and each cone contains 58 to 42 seeds on average. Winged seeds are released from the cones and are carried away by the wind. With the arrival of the monsoon, the falling seeds germinate. Its easy pollinating nature and its capacity to flourish in adverse environments contribute to its overpopulation in the mountains.

- No fodder capacity-

  The abundant Chir pine forest produces nothing edible for wild animals like monkeys or elephants, which lead the animals to stray into human habitat in search of food. Its leaves cannot be used as fodder for livestock, as they have a high acid content, which makes the land infertile. The depletion of edible plants and the increase of timbre species are affecting the habitat of herbivores, which also serves as an important prey base for carnivorous animals. This finally disrupts the food chain. The lack of fodder capacity within the monoculture of Chir pine trees in the Himalayas can also contribute to soil erosion, as there may be less plant material to hold the soil in place and prevent runoff.

- Lower albedo (reflectivity)-

  Pine trees have lower albedo (reflectivity) reflect less sunlight and absorb more of it. This means that the trees absorb more energy from the sun and release it as heat, which can increase the overall temperature of the environment. This can have an impact on the local climate and ecosystem. For example, if the temperature of a forest increases, it can affect the growth and health of other plants and animals in the area. Additionally, it can have an impact on the amount of water in the area, as higher temperatures can lead to increased evaporation rates, which can affect the water cycle.

- Felling ban of pine tree-

  Because of extensive tree chopping, the Uttar Pradesh (now Uttarakhand) government issued a 10-year prohibition on felling trees more than 1,000 meters tall in 1981. The restriction was then extended for another ten years. Because silvicultural fellings of Chir Pine forests were prohibited beginning in 1980, many of the areas designated for felling in working plans could not be felled. On December 12, 1996, the Supreme Court imposed a ban on tree cutting in UP (Uttarakhand was then a part of Uttar Pradesh) and Himachal Pradesh while ruling on a writ petition filed against illegal timber extraction from the Nilgiri forests and for the preservation of the bioreserve. The ban is still in effect, giving Chir pine trees immunity to felling and has been ever since growing and multiplying its population in the Himalayas, dominating over the native flora of the region.

- Biodiversity Loss-

  Pine trees can contribute to biodiversity loss in a variety of ways. For starters, pine trees are frequently planted in thick monoculture plantations that replace native flora. This can lead to a reduction in the diversity of plant and animal life in the area, as well as soil degradation and erosion. Furthermore, because of their poor fodder capacity, they cannot support as much animal life as other species of plants. This can result in decreased biodiversity and habitat loss for wildlife that rely on grazing livestock for food. Finally, pine trees are frequently planted in non-native locations, which can result in the displacement of native plant and animal species and contribute to biodiversity loss. Every year, forest fires kill many animals and useful plant species that are not fire-resistant like the pine trees, resulting in fauna and flora loss in the region.

Pine trees do not support food for animals, dry out springs, promote forest fires and exploit the local native biodiversity. All the above-mentioned factors contribute towards negative implications of the environment and contribute to climate change.

Primary Observations

Whilst the association with the G.B. Pant institute of Himalayan Environment, there were certain takeaways which align with the information that has been collected through the secondary sources. Below are the key points that were verified by the key informants.

- Sunil Pant (Director, G.B. Pant Institute of Himalayan Environment)-

  During the virtual conversation with Mr. Pant it was noted that pine trees were present in the Himalayas in the pre-colonial era although they were limited to certain areas and were not in a state of monoculture. It was during the colonial period that its plantation and population increased substantially altering the Himalayan ecosystem. He stated that due to the easy and early pollination of the pinecones and the ability of the Chir pines to grow and bloom in degraded or barren land has led to their overpopulation, replacing and overtaking native trees which are highly resourceful to the local environment, animals and the people such as Oak. It was also stated that due to the terrain and soil type of the Himalayas, not many species of plants can grow in the mountains even though Chir pines easily grow on those environments. The bright side of the situation is that the pine trees contribute to maintaining the green cover of the mountains, regardless of the comparative resource outcomes. He also confirmed that the dry pine needles from the Chir pine trees are the main and most easy source for the annual forest fires in the Himalayan region. These forest fires cause sizable damage to the local people, animals and the

whole of the environment. Regardless of all the foes that the Chir pine trees carry with them, they are one of the greatest sources of revenue for the local administration. Its timber and resin hold high commercial value, where over 50 quintals of resin are sources annually from Almora, Uttarakhand itself.

- Dr. GCS Negi (Scientist, G.B. Pant National Institute of Himalayan Environment)- During the interaction with Dr. Negi, certain eye-opening details were verified. Pine forest ecosystem has a multifaceted role to play in shaping the structure and functioning of other forest ecosystems (such as Oak and other broadleaf conifer forests of sub-tropical and temperate parts of the Himalayan region) and associated human activities. Many research studies suggest that Pine forests are responsible for their voracious use of soil water and drying up of mountain springs so crucial for the sustenance of the human beings, poor in floral and faunal diversity, vulnerability to wildfire due to resin rich leaf litter, loss of forest floor water holding capacity and prone to rainfall-runoff generated soil erosion and landslides, low fuel wood and fodder quality etc. It was understood that the main worry of foresters and ecologists is about its fast colonization into the socially valued Oak and mixed broadleaf forests thus reducing both the tangible and intangible ecosystem services of the native forests of this region. Also, recurrent forest fire in the Pine forests in the face of global warming is incurring huge loss to the wealth of the nation in terms of various forest goods and services, particularly rich biodiversity of medicinal and aromatic plants and wild edibles. He also verified that the Pine forests heat up the landscape and generate heat pillars up above the ground surface leading to large amounts of evapotranspiration and altering the site-specific climate (rainfall and temperature) regime.

Recommendations/What can be done?

We have learned that Chir pine trees are depleting the Himalayan ecosystem and contributing further to the agents of climate change. The Chir pine species being the most common tropical pine forest species in India, among all other forest kinds in Himalayan India is alarming. The debate if pine trees are native to India is highly valid as its large-scale plantation for the last 300 years do not seem to be adjusting well with the environment of the Himalayas and the ecosystem, as they are not providing the ecosystem services the most populous species should provide considering its number. Here are some methods of mitigation to address the havoc pines have been creating in the Himalayas

- Promote mix-plantation methods-

  For biodiversity conservation, a proper balance approach between revenue generation and environmental protection is required. As a result, the Finnish mixed tree plantation concept may be an intriguing model to examine for the Himalayas. The Finnish people live in a green and self-sufficient state because of pioneering and stringent conservation tactics such as rigorous replanting, placing culpability on industries for any environmental damage, and monitoring, supporting, and awarding green technologies. We can also encourage mixed tree plantations on the Himalayan slopes to avoid the harm caused by pine monoculture. Multiple cropping is possible even in orchards. Plantation of mixed trees prevents soil depletion, recharges springs, and improves water quality.

- Miyawaki Technique-

  The technique, which is named after the Japanese scientist Dr. Akira Miyawaki, has been extraordinarily effective, with over 17 million trees planted in 1700 places worldwide. The Miyawaki Method is used to establish mixed forests, which generates income prospects for people. The goal is to go beyond forest creation and ensure that forests and humans may thrive alongside each other rather than at the expense of each other. These forests are multi-layered and resemble the densest areas of native undisturbed forests. Because the process is based on giving the forest the best possible start, such forests can develop up to 10 times faster, be 30 times denser, and have 100 times more biodiversity. Promoting this technique in Van Panchayats to adapt plantation of native trees such as Oak would highly benefit the environment, animals as well as the people of the region likely.

- Implementation of Carbon Markets

  In the times of growing greenhouse gases emission, building and considering a carbon market to curb emissions is the need of the hour. Many countries around the world already operate their carbon markets, although India is still in its developing stage. As it was discussed earlier, the model of Tāmata Hauhā is an interesting example of how we can generate revenue, sequester carbon dioxide and also promote native flora. Although the company grows pine plantation for its fast growing and high yield characteristics, the Indian Himalayas could follow the same model but by limiting pine trees growth and planting other environmentally fruitful species of trees. In the Himalayas, where there is monoculture of Chir pine trees, foresters and stakeholders could start generating revenue from the pine trees and slowly replace the degraded or faulty trees with

native species. This model is further appropriate for the Western Himalayas as it would generate revenue from the living trees and not from chopping the Chir pine trees off, which would reduce the green cover. The pieces of barren land could also be targeted, as a properly functioning carbon market would require afforestation to generate the carbon credits required by the GHG emitting industries. India plans to have its first Emissions Trading System by 2025, although later it is, more would be the unaccounted carbon leakage in the environment.

- Amendments to the existing felling law-

  Because of the increased number of Chir pine trees, the water sources in our villages are depleting. Chir pines are responsible for both forest fires and farm fires where many shade-providing and fruit-bearing trees also get damaged in these fires. These forest fires are a regular phenomenon of the Himalayas, and pine trees are considered responsible for the rampant fire as they are the most fire prone. The existing ban on felling of trees over 1,000 meter in height should be amended in some way that would allow mixed as well as Miyawaki method of plantation, which would help replace Chir pines with native and fruitful flora such as Oak, Sal, Deodar etc.

- Better utilization of the Chir pine resources-

  Chir pines can be used for various other uses beside its resin production and timber, such as in the packaging and paper industry. It has the highest tear and burst factor among any species of trees used to make paper. The printing paper made from Chir pine trees also have good forming and acceptable strength properties, also having the characteristic for being used as electrical insulation paper. Using the pine trees from areas where there is overpopulation of the Chir pines can be utilized for manufacturing of products such as paper, as it would decrease the dependency on other species used for paper production such as Subabul. Those regulated cleared forests can slowly be shifted to another forest of resourceful species of trees that would bear benefits such as Oak.

- Focus on oak trees-

  The banj oak forest occupies only a narrow course of the Western Himalayas, but it is highly valued for the variety of organisms it supports, as well as the multifaceted benefits it provides to human residents of the region. It also serves as the backbone of the temperate moist forest biome, which occurs between 1,500 m and 2,700 m in the Himalayas. A protected oak forest's dense vegetation and leaf litter plainly play an important role in boosting rainwater percolation down

into the soil, recharging underground springs and streams. It is stated that as oak trees die, streams, springs, and waterfalls disappear. The leaves of the banj oak are also used for composting and feeding by the locals. The Chir pine brings only resin and timber, whereas the oaks bring firewood, feed for their cattle, fertiliser for their farms, a reliable water supply, and a plethora of forest products. Studies also indicate quantity and value of provisioning and regulating services provided by oak forests to the local people is higher than those provided by pine forests. If seedlings can be defended from grazing goats and cattle, and mature trees can be protected from harvesting, the environmental benefits of reforestation will be substantial. Barren hillsides might be replanted with elegant evergreen Himalayan oaks.

- Capacity building-

  Capacity building of local people can help conservation of native flora by increasing awareness about the importance of preserving local flora, providing training and resources to local communities and empowering them to take an active role in conservation efforts. When local people are empowered with knowledge and skills, they can become effective stewards of their natural resources. For instance, they can learn about the importance of preserving native flora and the benefits of conservation. They can also be trained in techniques such as seed collection, mixed cultivation, and reforestation, which can help to restore degraded habitats. Additionally, they can be provided with resources such as tools, equipment, and funding to support their conservation efforts. By involving local communities, especially women, in conservation activities, they can take ownership of the process and feel invested in the outcome. This can lead to long-term sustainability and better outcomes for both the environment and the people who depend on it.

- A pilot project-

  A pilot project can help conserve and preserve native flora by testing out new conservation approaches on a small scale before they are implemented more widely. This can help to identify potential challenges and opportunities, refine strategies, and build support among local communities and stakeholders. For example, a pilot project could focus on restoring a small area of degraded habitat using techniques such as seed collection, nursery management, and reforestation. The project could involve local communities in the restoration process, providing them with training and resources to support their efforts. The pilot project could also monitor the results of the restoration efforts, collecting data on the success of different techniques and

identifying areas for improvement. If successful, the pilot project could be scaled up to a larger area or replicated in other locations, helping to conserve and preserve native flora more broadly.

Conclusion/ Reflections

It can be understood that the Himalayan ecosystem in India is a fragile example considering the changes in forest cover, flora-fauna and temperature over the decades. Developments and infrastructures are being made in the virgin mountains to support the increasing demand of travel, tourism and recourses in the region. With the man-mountain equation altering as a result of greed and commercialization, forests are no longer regarded as a pure form of nature or of major value in terms of the environment and ecology. Instead, they have evolved into a business model as a means of making money. If this tendency is not reversed, it could lead to a huge ecological calamity in the future.

Although Chir pine monoculture is quite visibly prevalent in the regions of Uttarakhand and Himalayas, the resources they provide to the people, animals and the environment are not as significant as their huge numbers. They are told to be the reason for loss of water in the springs, having no fodder capacity, degrading the soil quality, enabling soil erosion and landslides, not allowing undergrowth for other plants, trees and blamed for being the main source of forest fires every year in the forest. The easy, early pollination and ability of growing on degraded soil as compared to other broadleaf trees such as Oak lead to its dominance and monoculture of the Chir pine trees.

However, Chir pine tree is a source of substantial revenue generation as they are a huge source of resin which is used for various activities such as making roadways etc. They also are a source of timber which is used in various commodities such as in railway sleepers, making furniture, crates and paper. Even though Chir pine trees are considered a major source of forest fire, it is said that the intensity and damage caused by fires in oak forest would have been much more hazardous. As the ground is covered with pine needles in pine forest, the fire spreads fast, only for a few seconds and it does not seep into the ground and stays on the surface. Also due to the resilient nature of the Chir pine trees, they grow at any barren land with not enough water. This has a bright side in that they contribute to afforestation of the Himalayas and maintain the green cover of the region.

With all the factors considered, a balance must be made between the environment conservation and the commercial revenue generation aspect of the Himalayans forests. There should be amends made to increase the forest cover of the resourceful native flora species such as Oak, Teak and Deodar in the

regions where Chir pines are predominant. This would allow more animal species to strive in the otherwise barren ecosystem of pine trees and would also benefit the local Himalayan people by enabling them to better water accessibility, more fodder capacity and making the ecosystem a more native one as they were the pre-colonial era before the exploitation of the native trees started and unplanned plantations took over for commercial gains, restoring the former glory of the mega-biodiversity hotspot of the great Himalayas.

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