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Gymnosperms that are critical for coniferous forest health may be steadily declining in response to climate change

by Hirra Azmat on 17 July 2023

- *Gymnosperm species of cold, high-altitude northwestern Himalayas are predicted to decline as their habitats reduce in the light of climate change impacts.*
- *Slow-growing gymnosperms have a relatively long lifespan and have varied adaptability to environmental changes, which is currently under-studied.*
- *A study that considered projected future climate variations predicted a severe decline in several*

gymnosperm species, including the Himalayn fir, Himalayan silver fir and Himalayan spruce trees.

- *Experts suggest several conservation strategies, including biotechnological interventions, creation of seed banks and assessment of tree phenology patterns.*

A recent study (https://link.springer.com/article/10.1007/s10113-023-02050-1) has revealed that most gymnosperm species that thrive in cold, high-elevation areas in northwestern Himalayas in Jammu and Kashmir may be at higher risk of losing their habitat. Among these species are the west Himalayan fir (*Abies pindrow*), Himalayan silver fir (*A. spectabilis*), and Himalayan spruce (*Picea smithiana*).

Jammu and Kashmir has a total forest cover of 20,230 square kilometres (https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-jammu-kashmir.pdf). These forests are characterised by the presence of gymnosperm species such as Himalayan deodar (*Cedrus deodara*), blue pine (*Pinus wallichiana*), silver fir (*Abies pindrow*), spruce (*Picea smithiana*) and Himalayan yew (*Taxus wallichiana*).

Gymnosperms, unlike angiosperms, don't bear flowers or fruits and produce seeds at the surface of scales or leaves, or at the end of stalks, forming a cone-like structure. The distribution of gymnosperms varies with altitude. They are well-adapted to cold environments and typically found in high-elevation forests.

Figures show (https://link.springer.com/article/10.1007/s10113-023-02050-1) that out of 88 gymnosperm species found in the Indian Himalayan Region, 41 are found in northwestern Himalayas in Kashmir, with 20 occurring in the wild and 21 under cultivation.

Gymnosperms tend to grow slower and generally live longer than angiosperms, thriving for hundreds of years. For example, the redwood tree (https://www.thekashmirmonitor.net/the-redwood-asias-only-surviving-plant-species-discovered-in-kashmir-csir-declares-it-heritage-tree/) (*Sequoiadendron giganteum*) conserved at Yarikhah Drug Farm (Tangmarg) in Kashmir is 150 years old.

However, with the northwestern Himalayan region experiencing rapid warming and extreme weather events, these ancient tree species are facing significant threats to their distribution and health.

A chir pine tree along Jammu-Srinagar National Highway. Photo by Hirra Azmat.

Why are gymnosperms important?

According to study author Irfan Rashid, the most significant role of gymnosperms is carbon sequestration, as they contain significant biomass and help regulate the climate. Rashid is an assistant professor at the department of botany at University of Kashmir.

"Angiosperms exhibit greater diversity compared to gymnosperm species worldwide as well as in northwestern Himalayas. However, when it comes to ecological

functions, gymnosperms surpass angiosperms. They fulfill various functions, with their primary and most crucial role in climate regulation," he said.

Conversation 4 Vie

Irfan emphasised that these evergreen species, like others, act as effective wind-breakers, slowing down soil erosion and protecting watersheds. "They are also a rich source of diverse economic and medicinal products, providing innumerable products, including timber, fuel, gums, resins, medicines and many more useful products," he said. Gymnosperms are widely used by the local communities as part of traditional medicinal systems. Additionally, the pine needles are used to make handicrafts and bio-briquettes which are a biofuel substitute to coal and charcoal.

Gaurav Zinta, a senior scientist at CSIR Institute of Himalayan Bioresource Technology, agreed that gymnosperms play a vital role in carbon sequestration and also serve as 'green mufflers', reducing noise pollution.

"One noteworthy aspect is their deep root systems, which allow long-term storage of captured carbon in the ground, thus interrupting the carbon cycle. In contrast, annual plants like wheat and rice also capture carbon, but when they are harvested the following year, the carbon is released back into the atmosphere, making them less effective biological systems for carbon sequestration," he said.

Zinta said that they emit Volatile Organic Compounds (VOCs) when there is unusually warm weather or heat. These compounds are involved in plant-to-plant communication as alarm signals. "Thus, gymnosperm species play a crucial role in the overall functioning of the forest ecosystem."

Himalayan deodar or Cedrus deodara. Rapid warming and extreme weather events in the northwestern Himalayan region is impacting the distribution and health of gymnosperms. Photo by Amit Kumar.

Climate change impacts on Himalayan gymnosperms

According to scientists, climate change in the Kashmir Himalayas can manifest as either decreased or increased precipitation (rain or snow), untimely rainfall, unusual weather phenomenon, or glacial melting.

Figures (https://india.mongabay.com/2023/01/warmer-winters-in-the-kashmir-valley-are-leading-to-early-flowering-of-the-gul-toor/) from the Meteorological Department, Kashmir have shown that the severity of winters has reduced and the frequency of sub-zero temperatures has also decreased over the last 40 years. In May 2023, Jammu and Kashmir recorded exceptionally high rainfall, making it one of the wettest months (https://www.thekashmirmonitor.net/may-wettest-month-in-decade-in-kashmir/) in the past decade.

"The changing climate is adversely affecting our mountain ecosystems. Not only is our mountain snowpack shrinking fast but it is also affecting our biodiversity enormously. As most

plants and trees that grow on mountains are immensely vital in climate regulation and rank high in traditional and modern medicinal systems, it is deeply worrying. Climate change poses a serious threat to plants at high elevations by relocating and pushing them to extinction," said Javaid M. Dad, a researcher at the University of Kashmir and lead author of the study.

He elaborated that each species has evolved to thrive in specific environmental factors. While they can adapt to minor environmental changes, their ability to adapt differs greatly. "At one end are species that adjust rapidly (generalists), and at the opposite end are species with limited adjusting ability (specialists). With minor exceptions, the high elevation plants or gymnosperms are generally specialists and are thus highly vulnerable to climate change."

The study aimed to take a closer look at the extent of future impacts of climate change, assessing the potential distribution of wild gymnosperm species. It considered current and projected future climate variations across the northwestern Himalayas to identify species with higher risks of habitat loss.

Using 1,200 occurrence records of 19 gymnosperm species distributed across the northwestern Himalayas, the projected changes were modeled over time periods of 2040-2060 and 2061-2080.

The findings revealed that under the projected future climate scenarios, all conifers except *Pinus roxburghii* are expected to show a steady decline in high potential areas (HPA) with the decline being most severe for *Abies pindrow*, *A. spectabilis*, and *Picea smithiana* in both near (2050) and distant (2070) futures.

Javaid pointed out that the risk of forest shrinkage appears relatively high across temperate forests of Kashmir in the future. "While some species may decline, few like

Pinus roxburghii will adapt better in the sub-tropical forests of Jammu. The risk is low towards the cold desert Ladakh where it seems to expand and occupy higher mountain summits."

Another review (https://forestecosyst.springeropen.com/articles/10.1186/s40663-017-0100-4) published in the journal *Forest Ecosystems* stressed that the Himalayas are highly susceptible to natural hazards and climate change impacts and highlighted the need for better assessment of the ecological and genetic diversity of Himalayan conifers.

Read more: Kinnaur's chilgoza pine trees make way for hydropower projects (https://india.mongabay.com/2022/05/kinnaurs-chilgoza-pine-trees-make-way-for-hydropower-projects/)

Case studies of conifers around the world

Wajid Waheed, a DBT-Ramalingaswami Fellow at CSIR-Indian Institute of Integrative Medicine, Jammu, emphasised on the role of biotechnological interventions and improved forest management strategies to mitigate climate change impacts on high-altitude plant biodiversity. "This includes identification and preservation of elite gymnosperm genotypes across the northwestern Himalayas and development of climate resistant varieties through either classical breeding approaches or by using genetic engineering and synthetic biology techniques," he said. Elite gymnosperms are populations/collections/ accessions that are known to/bred to perform better under different climatic conditions, because of the inherent genetic variations that occur in populations.

He also noted that targeted interventions for commercialisation of gymnosperm species could be planned, as successfully done in New Zealand, Canada and the United States.

"Most importantly, the adequate funding in forest research will help in better understanding of Himalayan gymnosperms and their response to climate change," Wajid said.
In countries like New Zealand, the planted forests comprise predominately introduced conifer species including Radiata pine (*Pinus radiata),* which makes up 90% of tree cover and Douglas fir (*Pseudotsuga menziesii*), comprising 6%.

Abies pindrow at Lidderwath Pahalgam. Photo by Anzar Khuroo.

"Studies show that mean temperatures of New Zealand will increase between +0.7 to +1 degrees Celsius by 2040 and +0.7 to +3 degrees Celsius by 2090," said Glenn Thorlby, a plant molecular biologist and Group Leader at New Zealand's Premier Forest Research institute, SCION. "The region will experience increase in extreme hot days. Further, the modelling for *Pinus radiata* suggests that increased carbon dioxide and higher temperatures will boost growth leading to more biomass but taller thinner trees."
Glenn added that these trees may be more exposed to predicted higher winds, drought and wildfires. "It is also thought that milder winters will lead to increased numbers of

mammalian and insect pests and the introduction of novel microbial pests is also likely."

He believes that unlike the rest of the world, native conifers dominate rainforests in New Zealand, compared to flowering plants. "There are 18 native conifers and all are endemic. These are less studied than introduced plantation species, for which a hundred years of comprehensive growth data is available." According to Glenn, they are generally slow growing and it is anticipated that climate change will affect their range. Introduced microbial pathogens are already having a negative effect and this could worsen. "Some studies suggest that climate change may lead to extinction of some of these native trees in the longer term."

Lack of data and conservation measures

In India, experts are calling for no long-term monitoring to assess the impact of climate change on gymnosperm species.

Forests often exhibit yellowed patches where a large number of trees have died, and this phenomenon is known as forest dieback. According to Zinta, such dieback can be attributed to reduced precipitation, increased heating, diseases, and other related factors. "In other words, forest dieback may indicate the impact of climate change, but accurate and long-term monitoring is required to ascertain these trends in forests of the Indian Himalayas and based on the data obtained, conservation measures can be devised," he said.

Javaid stresses that building seed banks on a priority basis can secure the species from the threat of extinction. "The habitats where gymnosperms may vanish could be utilised as *in-situ* (on-site) conservation areas. In this approach, we can adopt technological solutions like creating a seed bank or gene

bank and save it for posterity. On the contrary, the habitats wherein it may expand could be developed as *ex-situ* conservation (off-site) areas."

PhenoMet station to study climate impact on pine forests

The CSIR-Institute of Himalayan Bioresource Technology (CSIR-IHBT), Palampur, in collaboration with the Space Application Centre (SAC) of the Indian Space Research Organisation (ISRO), has set up a PhenoMet station to study the impact of climate change on pine forests in Himachal Pradesh.

"We have observed that the forest fire incidences have increased in last two decades particularly in the Himalayan regions due to changing climatic conditions leading to forest degradations and chir pine forests have higher fire frequencies amongst these fire-sensitive forests," said Amit Kumar, Senior Principal Scientist and Head of the Environmental Technology Division of the CSIR-Institute of Himalayan Bioresource Technology (CSIR-IHBT).

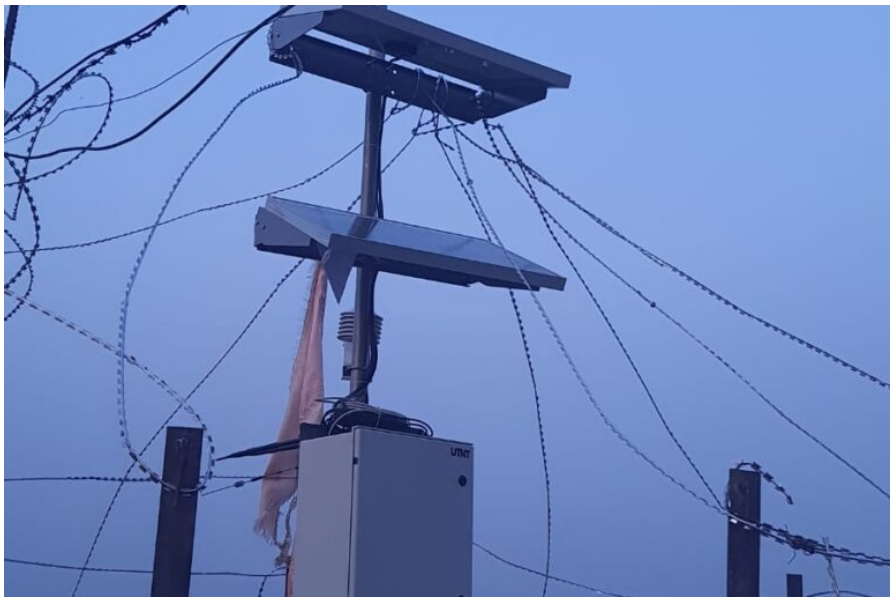
Kumar added that forest phenology is one of the important indicators of climate change.

"Vegetation phenology is the timing of seasonal developmental stages in plant life cycles including bud burst, canopy growth, flowering, and senescence, which are closely coupled to seasonally varying weather patterns," he said.

He said that PhenoMet stations attempt to record and understand phenological processes and their relation to weather conditions.

According to him, the PhenoMet station installed in the Hamirpur area is equipped with a camera that will record time lapses and an automated weather station which will record pictures of the surrounding pine forests every 30 minutes, along with various weather parameters such as air temperature, relative humidity, rainfall, active photosynthetic

radiations, and so on. "The study will help in understanding the nature and trend of phenological changes in the pine forest on a regional scale using long-term archived satellite data. At the same time future scenarios can also be simulated for the projected climatic changes."



A PhenoMet station. Such stations record and understand phenological processes and their relation to weather conditions. Photo by Ami Kumar.

Kumar maintained that PhenoMet stations are being installed at 17 locations throughout the country, with eight having been installed so far under ISRO Geosphere Biosphere Programme (IGBP). These stations will be expanded to Himalayan moist temperate forests in Gulmarg, Jammu & Kashmir, tropical wet evergreen forest in Sholayar, Kerala, subalpine and alpine forest in Tawang, Arunachal Pradesh, and tropical dry deciduous forest in Gir, Gujarat, covering major habitat types in India.

"This way, we will have a phenology calendar and PhenoMet models to understand forest dynamics of the entire forest system in India that will further add to our understanding of changing temperatures and the necessary climate action required."

Conservator of Forests in South Kashmir, Irfan Ali Shah emphasized the ecological fragility and sensitivity of the upper reaches or alpine areas. "They act as carbon sinks and offer an abundance of valuable plants with medicinal and aromatic properties, and wildlife diversity. Consequently, these areas require enhanced management and measures."

Shah said that several management plans have been meticulously developed for priority areas situated at high altitudes, including Affarwat in Gulmarg, Daksum, Kazinag and Lachipora Wildlife Sanctuary in North Kashmir, Hirapora Wildlife Sanctuary in South Kashmir.

To combat forest fires, for example, the use of technology is employed to capture real-time satellite images in Jammu and Kashmir. During summers, the accumulation of dry needles on the ground hampers regeneration and poses a fire hazard owing to slow decomposition. "By promptly reporting incidents from the field staff to the control room, the dissemination of real-time information enables swift action to gain control over fires and minimise environmental damage," he said.

Additionally, Shah explained the practice of enrichment planting in forests, which involves reintroducing plant or tree species to decrease their population. "This approach facilitates the restoration of plant diversity in targeted areas."

Read more: Scientists develop a toolkit to identify high conservation-value areas (https://india.mongabay.com/2023/06/a-toolkit-to-identify-high-conservation-value-areas/)

Banner image: The Himalayan deodar or *Cedrus deodara.* Gymnosperms don't bear flowers or fruits and produce seeds at the surface of scales or leaves, or at the end of stalks, forming a cone-like structure. Photo by Amit Kumar.

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