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Climate-Smart and Resilient Agriculture for the Himalayan Region of Uttarakhand

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ABSTRACT

Uttarakhand Himalayan region is facing a serious agricultural crisis due to the rapid impacts of climate change. Rising temperatures and unpredictable weather patterns such as unusual rain during monsoons, shrinking glaciers and more extreme weather events, all threaten the farmers' livelihoods in this area. However, there is hope, Climate Smart Agriculture (CSA) offers a solution with a focus on improving productivity, resilience and mitigation. In this Article, I will discuss each of these aspects, explore the main climate-related challenges faced by farmers in Uttarakhand and also provide an example of how traditional farming methods can be combined with new science-based solutions. I will also show how institutions can support long-term agricultural sustainability.

***Keywords*:** Climate-smart agriculture, Uttarakhand, Himalayan farming, millets, agroforestry

1. Introduction

In the Himalayas, farmers have cultivated their lands for centuries. Their environment features like terraced fields carved into steep hills, with rivers flowing through forests. Farmers in Uttarakhand grow crops like *mandua* (finger millet) and *jhangora* (barnyard millet). They rely on their local knowledge and a detailed understanding of the weather conditions in their valleys, including the length of the rainy season, the amount of rainfall and the environmental traits of their area. However, this knowledge is facing new challenges. The climate in the Himalayas is changing; it is warming more quickly than in most other regions of India. The International Centre for Integrated Mountain Development ***ICIMOD, (2019)*** reports that the climate in the Hindu Kush Himalayan area is shifting at a faster rate than the global average and this trend will continue under any climate change scenario. As a result, mountain agriculture is suffering from unpredictable rainfall, extended droughts due to lower moisture levels, flash floods, increasing soil erosion and difficulty maintaining traditional planting and harvesting schedules. These challenges are not theoretical, for the roughly 800,000 farming families in Uttarakhand, these issues are their everyday realities. Now, the urgent question today is: *How do we farm smarter so that farmers, ecosystems, and food systems can all survive and thrive together?*

2. The Climate Crisis in Uttarakhand's Agriculture

Uttarakhand is facing a series of challenges in context of farmers due to climate change. Glaciers that have historically fed rivers are disappearing at a rapid pace, threatening the water supply for irrigation and drinking. The retreat of mountain glaciers initiates a cascading impact on water scarcity, soil erosion, and the drying up of springs and streams ***Dimri et al. (2025)***. Farmers are also experiencing more unpredictable rainfall and longer dry spells, followed by sudden cloudbursts that ruin crops and wash away vital topsoil from the area's steep slopes. Additionally, environmental changes influenced by climate change are leading to a slower crisis. The agro-biodiversity of traditional climate-resilient crops like mandua, jhangora, and ogal (buckwheat) is gradually being replaced by chemically-intensive and market-focused crops over the time ***Pandey & Kumar, (2024)***. This shift has made farmland more fragile, reducing its ability to resist the impacts of climate change. Agricultural systems need to adjust to the changes happening in the mountains.

3. Climate-Smart Agriculture: An Integrated Framework

Climate Smart Agriculture (CSA) is a way to grow food sustainably. It helps to increase productivity, build resilience to change, reduce or eliminate greenhouse gases, support national development goals and achieve food security. CSA has three connected elements known as pillars: productivity, resilience, and mitigation ***Lipper et al. (2014)***. In the Himalayas, CSA is not about importing expensive foreign technology. Instead, it combines ecological knowledge from traditional farming systems with modern science, policies and community-driven efforts for long-term success. Climate-smart Agriculture is viewed as a framework to ensure that local conditions, knowledge, and agency create a strong foundation for lasting solutions.

4. Key Climate Smart Agriculture Strategies for Uttarakhand

4.1 Revival of Traditional Millet Crops

The revival of ancient cereal crops like *mandua, jhangora*, and *ogal* is one of the best and most accessible way to promote sustainable farming and adapt to climate change in Uttarakhand. These annual crops are very resilient; they can survive long dry spells, grow in worn-out soils and require little artificial farming support. They also offer a variety of important nutrients, such as protein, fiber, iron and zinc ***Panwar et al. (2016)***. Unfortunately, in recent decades, commercial farming has pushed many of these crops and their related cultural knowledge to the sidelines. ***Gururani et al. (2021)*** present data showing that revitalizing the *barahnaja* (multi-cropping) system, which includes at least 12 different crops such as millets, legumes, oilseeds and vegetables, it illustrates how agriculture can be made more sustainable and resilient to climate change by relying on the traditional farming practices.

4.2 Agroforestry and Mixed Farming Systems

Agroforestry is an effective way to stabilize the hillside soils, reduce erosion, lower soil temperature and it also provide farmers an extra income by growing trees alongside crops. Long-term agroforestry studies in the northwestern Indian Himalayas have demonstrated substantially higher soil organic carbon stocks compared to conventional monoculture farming ***Saleem et al. (2023)***. As rainstorms become more common and intense in the Himalayan region, tree roots help to hold the soil in its place, preventing it from washing away. Farmers can also earn money from trees on their farms through timber, fruits or by animal feed. This provides them with some security in case their cereal crops do not perform as expected. ***Trivedi et al. (2022)*** found that diversified, multi-component agricultural systems in Uttarakhand are much more resilient to climate variability than chemical-dependent and mono-crop systems.

4.3 Water Conservation and Micro-Irrigation

The scarcity of water poses a serious threat to Himalayan agriculture. This is due to the melting of ice caps and less spring runoff. Farmers can now use new technologies like drip and sprinkler irrigation through programs like Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) that is a Government of India scheme to ensure water security. Micro-irrigation technologies such as drip and sprinkler systems can boost crop productivity by 20 to 90 per cent for various crops while significantly reducing water consumption compared to traditional flood irrigation ***Kumar et al. (2024)***. These methods help them to use all the available water more efficiently. Additionally, collecting rainfall runoff i.e. rain water harvesting at the farm can offer extra support for farmers. Together, these two techniques provide reliable sources to help farmers to manage the challenges of unpredictable water supplies.

4.4 Organic Farming and Soil Health

Soil health in the Himalayas matters for sustaining life in these landscapes as well as for producing the crops. The steep, terraced slopes throughout the region are subject to significant erosion risk. Healthy soils are the unseen support system for resilient agriculture. Composting, green manuring and limiting chemical fertilizer usage can improve the health of soils by enhancing their ability to hold water, as well as supporting beneficial soil microbial communities. Research conducted in Himalayan foothills confirms that organically managed soils harbour significantly richer and more active microbial communities than those under conventional chemical-intensive agriculture, and that long-term organic inputs substantially improve available soil nitrogen, phosphorus, and potassium ***Suyal et al. (2024)***. Such soils can recover more fully and quickly from climate stress than degraded, input-dependent soils that rely on excessive chemical inputs.

4.5 Weather Information and Early Warning Systems

Quick and accurate weather forecasts can make all the difference in farmers being able to save their harvests versus losing an entire season due to poor weather conditions. Mobile agro-advisory services provide timely notifications of approaching

frost, unseasonal rainfall, hail storms or dry weather so that farmers can act pre-emptively to cover their crops, reschedule sowing date, or can harvest early. Extending this kind of technology to remote mountainous areas of Uttarakhand that have limited connectivity is essential and has the potential for a high impact.

5. Institutional and Policy Landscape

An increasing number of organizations are working to create a climate-resilient ecosystem in the hilly region of Uttarakhand. The GB Pant National Institute of Himalayan Environment is researching the effects of climate change on the ecosystem and their management in the Indian Himalayan Region. ICAR-Vivekananda Institute of Hill Agriculture has also developed climate-resilient crops and farming systems that is suitable for high-altitude areas. Communities are restoring degraded forest-farm ecosystems by improving hillside conditions through village forest councils known as Van Panchayats. At the national level, programs like the National Mission for Sustaining Himalaya Ecosystem (NMSHE) under India's National Action Plan on Climate Change also offer policy guidance that aimed at conserving Himalayan ecosystems, including those of farmers who depend on these resources. However, challenges related to research, policy and community implementation continue to create a significant obstacle that need to be addressed quickly.

6. Conclusion

Uttarakhand's terraced farms are much more than just agricultural land. They showcase centuries of human creativity in a challenging environment. This relationship between people and the mountains has been refreshed with every growing season. Unfortunately, this bond is now facing threats from climate change. Climate-smart farming methods, tailored to the unique eco-cultural conditions of the Himalayas, offer a promising way forward. These methods should blend the revival of traditional crop diversity with modern farming practices. They should also include water-saving agriculture and time-tested conservation techniques, along with scientific knowledge. Ultimately, making climate-smart agriculture a reality that requires strong cooperation among government bodies, research institutions, community organizations and local communities. Change is coming to the mountains; however, with the right sharing of information, tools, and collaboration, farmers in Uttarakhand can continue their work. They will support those who rely on their farms, as well as the rivers and towns that will develop downstream in the future.

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