BEYOND THE HEADLINES:

2026 UNFOLDING

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INSIDE

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Beyond the Headlines: 2026 Unfolding
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Preface

It is with immense satisfaction and heartfelt gratitude that we present the third edition of *Beyond the Headlines*. What began in 2023 as an effort to look beyond breaking news and explore the deeper realities shaping our world has now completed three meaningful years. The overwhelming response from our readers, scholars, students, and professionals has continually encouraged us to carry this journey forward.

The year 2026 has been one of profound change and uncertainty. From devastating floods and intensifying climate concerns in the Himalayas to shifting geopolitical dynamics in Nepal and South Asia, from the rapid rise of artificial intelligence to debates on technological self-reliance and global economic transitions, the year has reminded us that the world is changing faster than ever before.

Selecting only a few themes from such a dynamic year was no easy task. Yet our editorial approach has always been guided by relevance: relevance to India and, equally importantly, to the Indian Himalaya. As an initiative of Jagriti Media, rooted in the Himalayan state of Uttarakhand, we feel a special responsibility to highlight issues that directly impact the region, its people, and its fragile ecosystems.

The aim of *Beyond the Headlines* has never been merely to retell stories already known to the public. News informs us of events; this volume seeks to uncover the realities behind them. It brings to the forefront the voices of scientists, researchers, academicians, and experts whose evidence-based insights and lived experiences often remain unheard beyond academic and professional circles.

In many ways, this volume serves as an archive of our times, a repository of ideas, concerns, and reflections on some of the most significant issues of the year. It preserves not only events but also the deeper narratives and expert perspectives that help us understand an increasingly complex world.

As we present *Beyond the Headlines: 2026 unfolding*, we do so with gratitude to our contributors and readers and with a renewed commitment to creating a platform where knowledge, evidence, and thoughtful dialogue continue to illuminate the stories that shape our present and our future.

Dr. Shachi Negi
Anubha Rawat
Editors
Beyond the Headlines: 2026 Unfolding

Jagriti Media

Beyond the Headlines: 2026 Unfolding

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India-Nepal Relations in a Changing Geopolitical Landscape: A Conversation with Surendra Singh Pangtey

Dr. Shachi Negi

The Himalaya beyond Borders

Some encounters begin long before two people actually meet.

For years, I have heard about Shri Surendra Singh Pangtey, a historian of the Himalaya, a chronicler of its forgotten stories, and a man whose life has been deeply intertwined with the mountains and their people. I had read his books on the culture and history of the central Himalaya and had often found myself captivated by the depth of his understanding of the region. His writings carried not merely historical facts but the memory of a civilization that has long flourished across mountain passes, trade routes, and cultural exchanges.

When the editorial team of *Beyond the Headlines: 2026 Unfolding* began discussing the themes for this edition, one subject stood out prominently: the changing geopolitical landscape of Nepal and its implications for India and the Himalayan region. The question then arose: who could help us understand these developments beyond the daily headlines and political rhetoric?

A senior journalist answered that question without hesitation:

"You must speak to Surendra Singh Pangtey."

The suggestion seemed almost inevitable.

The objective of *Beyond the Headlines* has always been to bring our readers closer to those who have witnessed realities on the ground, individuals whose understanding is shaped not merely by academic inquiry but by lived experiences and historical memory.

Born and brought up in Munsyari, in Uttarakhand's Pithoragarh district on the border with Tibet and Nepal, Pangtey ji belongs to a region that has historically served as a bridge between India, Tibet, and Nepal. An officer of the Indian Army, a distinguished member of the Indian Administrative Service, an eminent author, and one of the foremost scholars of Himalayan culture, he has devoted his life to documenting the history and traditions of the Himalayan people.

Speaking with him felt less like conducting an interview and more like embarking on a journey through the many layers of Himalayan history.

India and Nepal: A Civilizational Relationship beyond Politics

In recent years, Nepal has increasingly occupied a prominent place in South Asian geopolitical discussions. The country's internal political developments, its evolving relations with China, and renewed debates over territorial issues have generated considerable interest in India. Yet, for those who have spent a lifetime observing the Himalayan region, the relationship between India and Nepal transcends the immediate concerns of diplomacy and strategic calculations.

As someone who has witnessed the transformations of the Himalayan region both as an administrator and as a native of the borderlands, Shri Surendra Singh Pangtey offers a perspective deeply rooted in history and lived experience.

When asked about the recent geopolitical developments in Nepal and the future of India-Nepal relations, Pangtey ji's response moves beyond contemporary politics and returns to a more fundamental reality: the enduring interconnectedness of the two nations.

He believes that Nepal itself is acutely aware of its close economic relationship with India. Despite being an agrarian country, Nepal's domestic production often falls short of meeting the needs of its population. A substantial portion of essential commodities, including food and daily necessities, continues to reach Nepal through India, making economic cooperation between the two countries not merely desirable but indispensable.

At the same time, he acknowledges the changing geopolitical environment in the region. According to him, China has consistently sought to expand its influence in Nepal, and these efforts have undoubtedly shaped the country's political discourse and strategic choices over the years. However, he is quick to point out that political developments alone cannot define the nature of India-Nepal relations.

> **"Beyond politics, there remains a deep reservoir of goodwill towards India among the Nepali people."**
> *- Surendra Singh Pangtey*

For Pangtey ji, the true strength of India-Nepal relations lies in the centuries-old bonds that have connected the people of the two countries. The relationship is sustained by shared history, religious traditions, cultural affinities, and human connections that extend far beyond official diplomatic engagements.

India and Nepal share one of the world's most unique international boundaries, an open border through which people, ideas, traditions, and families have moved freely for generations. Millions of people on both sides of the border have familial, social, and cultural ties that cannot be replicated elsewhere. Villages, communities, and even festivals often reflect a shared cultural heritage that predates the modern nation-state itself.

In Pangtey ji's view, the relationship between India and Nepal has evolved organically over centuries. It is not a partnership created solely through treaties, political agreements, or strategic necessities. Rather, it is a relationship born of a shared civilizational experience, nurtured through centuries of interaction, pilgrimage, trade, and cultural exchange.

He notes that governments may change and political leadership may occasionally pursue different strategic priorities. External powers may seek influence in Nepal, and domestic political considerations may periodically shape public discourse. Yet, Nepal cannot overlook the realities of geography and economics that continue to bind it closely with India.

For him, the future of India-Nepal relations rests not merely on strategic calculations but on strengthening the foundations that have sustained the relationship for centuries mutual trust, economic cooperation, cultural exchanges, and people-to-people engagement.

"The relationship between India and Nepal is not merely strategic; it is civilizational."

— Surendra Singh Pangtey

As our conversation progressed, it became increasingly clear that Pangtey ji views the relationship between the two countries through the lens of history rather than the immediacy of political events. Political currents may shift and geopolitical equations may evolve, but the deep-rooted civilizational bonds between India and Nepal possess a remarkable resilience.

For him, the future of India-Nepal relations ultimately lies in recognizing and preserving these enduring connections, ties forged not by governments, but by geography, history, culture, and centuries of shared human experience.

Remembering Tibet: Trade, Memory, and the Lost Himalayan World

The story of the Himalaya cannot be understood through political boundaries alone. Long before modern nation-states, the mountains were connected by a web of trade routes, pilgrim trails, and cultural exchanges that linked communities across vast and difficult terrains. The Himalaya was not a frontier that divided people; it was a bridge that connected civilizations.

Among the most enduring of these relationships was the centuries-old bond between India and Tibet. For generations, the people of the Himalayan borderlands lived in close interaction with Tibet, sharing not only commerce but also customs, traditions, and a common way of life shaped by the mountains.

When asked about his memories of this bygone world and the impact of the closure of the Indo-Tibetan trade routes, Shri Surendra Singh Pangtey's response is marked by both nostalgia and a deep sense of loss.

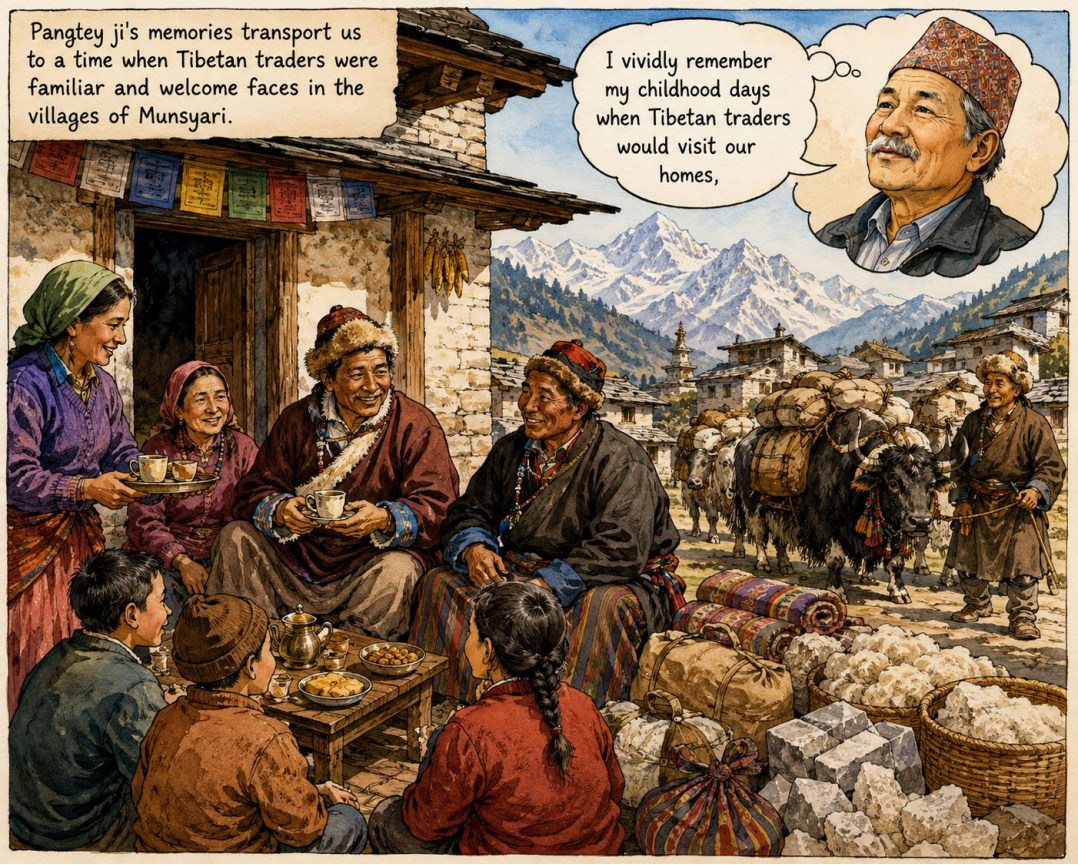
For him, the relationship between India and Tibet was never merely an economic arrangement.

> **"The relationship between India and Tibet was much more than a commercial exchange; it was a centuries-old civilizational and cultural bond."**
>
> *— Surendra Singh Pangtey*

The people of the Himalayan region, particularly the Bhotiya communities of Uttarakhand, maintained close ties with Tibet through trade, tradition, and regular interaction. These connections shaped not only the economy of the region but also its social and cultural fabric.

Pangtey ji's memories transport us to a time when Tibetan traders were familiar and welcome faces in the villages of Munsyari.

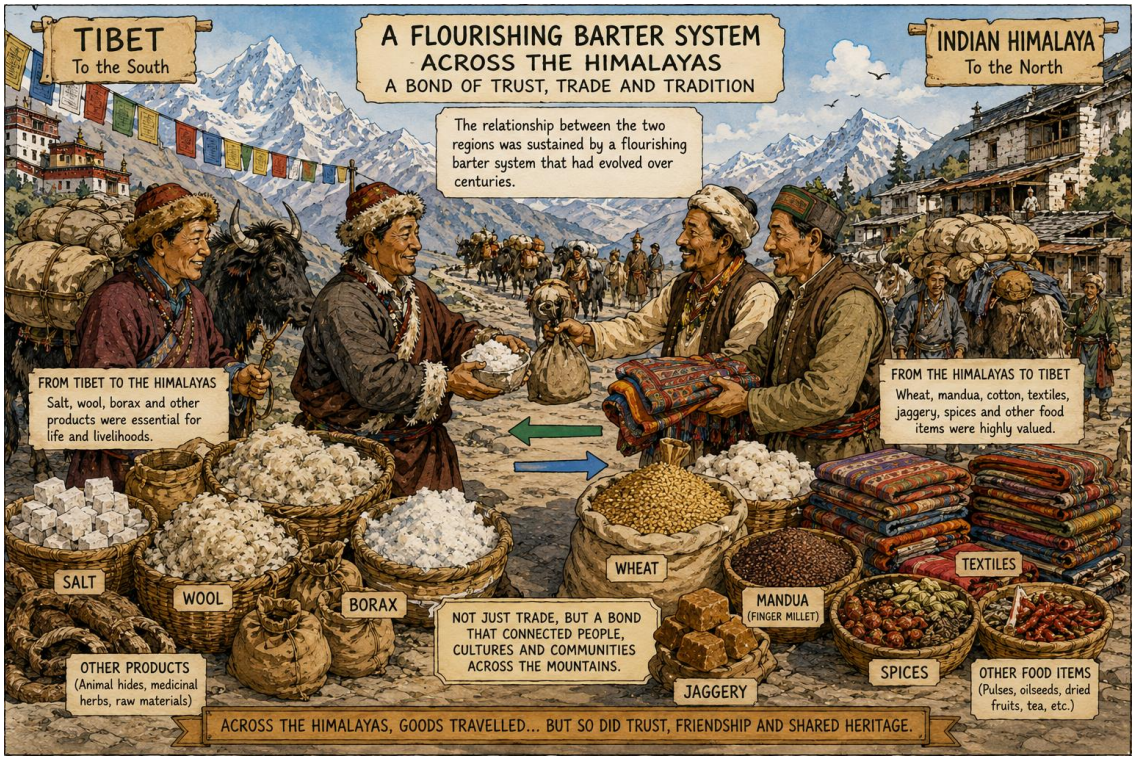
"I vividly remember my childhood days when Tibetan traders would visit our homes," he recalls. "They were always welcomed with warmth and hospitality."



Their visits were not treated as business transactions alone. They were occasions of friendship and community interaction. Families opened their homes to the traders, shared meals with them, and exchanged stories that transcended political and geographical boundaries.

The Tibetan traders, he remembers with a smile, were particularly fond of Indian food. Agricultural production in Tibet was limited due to the harsh climate and terrain, and Indian food products held special significance there.

The relationship between the two regions was sustained by a flourishing barter system that had evolved over centuries. Tibet supplied the Himalayan communities with salt, wool, borax, and other products, while Indian traders carried wheat, mandua (finger millet), cotton, textiles, jaggery, spices, and a variety of food items across the mountain passes.



Among these commodities, sattu occupied a particularly important place in the Tibetan diet, and Indian agricultural produce was highly valued across the plateau.

For the people of the Himalayan borderlands, this trade was not supplementary; it was fundamental to their existence.

> **"For us, trade with Tibet was the backbone of the economy."**
>
> *— Surendra Singh Pangtey*

Agriculture alone could not sustain livelihoods in these high-altitude and mountainous regions. The rugged terrain and limited cultivable land made trans-Himalayan trade the principal source of income for countless families.

The annual trade caravans became an integral part of life in the border villages.

As children, Pangtey ji and his contemporaries grew up listening to stories of traders crossing high mountain passes, enduring harsh weather, and returning with goods and experiences from distant lands.

The idea of going to Tibet held a special fascination.

"It was considered an adventure," he says. "A cherished dream."

To the younger generation of that era, becoming a trader was not merely an occupation; it was a symbol of courage, enterprise, and connection with a larger Himalayan world.

The trade routes themselves were much more than economic corridors.

They were cultural highways.

Through them flowed not only goods but also languages, beliefs, songs, traditions, and relationships. Communities on either side of the mountains developed deep bonds of trust and mutual dependence. The Himalaya, in those times, was an interconnected civilizational space where movement and interaction were part of everyday life.

However, this world changed dramatically following the Chinese occupation of Tibet and the subsequent closure of the traditional trade routes.

The consequences, according to Pangtey ji, were profound.

The cessation of this centuries-old trade deeply affected the border communities of India. Entire local economies that had evolved around trans-Himalayan

commerce suddenly collapsed. Families that had depended on trade for generations were forced to seek alternative livelihoods, and many traditional occupations gradually disappeared.

The impact was not limited to India alone.

The closure of these routes also had repercussions for Nepal, although Nepal subsequently developed new economic and infrastructural links with China.

For the people of the Indian Himalaya, however, the closure of the Indo-Tibetan trade marked a decisive turning point in their history.

> **"The closure of the Indo-Tibetan trade was not merely an economic loss; it marked the end of an era."**
>
> — *Surendra Singh Pangtey*

It signified the disruption of age-old cultural exchanges, the decline of traditional livelihoods, and the gradual fading of the unique trans-Himalayan networks that had connected communities across the mountains for generations.

Listening to Pangtey ji, one realizes that the story of Indo-Tibetan trade is not merely an account of commerce. It is the story of a lost Himalayan world, a world where borders were more porous, relationships more intimate, and the mountains themselves served as pathways of connection rather than lines of separation.

In many ways, his memories remind us that the Himalaya once represented a shared civilizational space, bound together by human relationships and cultural exchanges whose echoes can still be heard in the memories of those who lived through that remarkable era.

The Territorial Question and the Future of India-Nepal Relations

In recent years, one issue has repeatedly resurfaced in discussions on India-Nepal relations, the territorial claims surrounding the Kalapani-Limpiyadhura-Lipulekh region. Nepal's renewed assertions, based on its interpretation of historical documents and the Treaty of Sugauli of 1816, have generated intense political and diplomatic debates in both countries.

For many observers, these developments raise an important question: Are the foundations of India-Nepal relations changing? Can territorial disagreements and evolving geopolitical dynamics alter a relationship that has historically been sustained by deep cultural and civilizational ties?

When I posed this question to Shri Surendra Singh Pangtey, he responded with the measured perspective of a historian who has spent decades studying the Himalayan region and its borderlands.

According to him, the recent revival of territorial claims must first be understood within its political context.

He points out that these issues are not entirely new. Similar claims and debates have surfaced under previous governments in Nepal as well. The present political leadership, he believes, has once again brought these matters into public discourse largely because such issues resonate strongly with domestic political sentiments.

In his view, the renewed territorial assertions are, to a considerable extent, a political strategy aimed at influencing domestic opinion and consolidating public support. Nationalist narratives, particularly those related to territory and sovereignty, often become powerful tools in political discourse.

However, Pangtey ji is equally clear in stating that Nepal's leadership is fully aware of the historical and geopolitical complexities surrounding these border regions.

"The leadership in Nepal understands that these claims are unlikely to bring about any immediate territorial change," he observes.

Having devoted years to researching the history of the Himalayan borderlands, Pangtey ji approaches the issue not merely as a commentator but as a scholar of the region's historical records and administrative evolution.

> **"As a historian and researcher of the Himalayan region, I have studied and documented the historical evidence pertaining to these border areas."**
> *— Surendra Singh Pangtey*

Based on his research and examination of historical evidence, he believes that the territories presently claimed by Nepal have historically been administered as part of India.

The significance of this region, however, extends far beyond questions of cartography and political boundaries.

For India, the areas encompassing Adi Kailash (Chhota Kailash), Om Parvat, and Nabhidhang possess immense religious, cultural, and civilizational importance. These sacred landscapes have for centuries occupied a special place in the spiritual imagination of the Indian subcontinent and remain deeply connected with the traditions and beliefs of the Kumaon Himalaya.

Adi Kailash, in particular, has emerged as an important pilgrimage destination and continues to attract devotees and spiritual seekers from across the country. For the people of Uttarakhand, these mountains are not merely geographical spaces but repositories of faith, history, and cultural memory.

Yet, despite the emotional and political sensitivities surrounding the issue, Pangtey ji remains optimistic about the future of India-Nepal relations.

He does not believe that temporary political narratives can fundamentally alter the nature of the relationship between the two countries.

> **"While political narratives may occasionally create tensions, they cannot weaken the enduring relationship between India and Nepal."**
> *— Surendra Singh Pangtey*

For him, the ties between India and Nepal are far deeper than the political rhetoric of any particular moment. They are rooted in centuries of shared history, religious traditions, cultural exchanges, and people-to-people interactions that have withstood changing governments, shifting geopolitical equations, and periodic diplomatic disagreements.

The open border between the two countries, the interwoven social and familial connections, and the shared civilizational heritage continue to provide a strong foundation that transcends contemporary political disputes.

Listening to Pangtey ji, one is reminded that border disagreements, while important, represent only one dimension of India-Nepal relations. The larger story is one of extraordinary historical continuity, a relationship nurtured over centuries by geography, culture, faith, and human connections.

Political narratives may shift, governments may change, and territorial questions may periodically dominate headlines. Yet, as Pangtey ji suggests, the enduring strength of India-Nepal relations lies in something far deeper: a civilizational bond that has repeatedly demonstrated its resilience amid changing times.

China's Growing Influence in Nepal and the Himalayan Geopolitical Question

No discussion on contemporary Nepal can remain untouched by the question of China's growing presence in the Himalayan region. Over the past two decades, China's expanding economic investments, infrastructural projects, and increasing diplomatic engagement in Nepal have prompted a wider debate in South Asia. For many observers, these developments have raised an inevitable question: Could Nepal one day witness a situation similar to that of Tibet?

The question is particularly significant because the Himalaya has long been viewed not merely as a geographical barrier but as a strategically sensitive zone where the interests of major powers intersect.

When I put this question to Shri Surendra Singh Pangtey, his response was immediate and unequivocal.

> **"I do not think such a situation is likely to arise in the case of Nepal. The circumstances of Nepal and Tibet are fundamentally different."**
> — *Surendra Singh Pangtey*

For Pangtey ji, any comparison between Nepal and Tibet overlooks the profound historical and political differences between the two regions.

Nepal, he explains, is an independent and sovereign nation, possessing its own political institutions, democratic processes, and a long history of statehood. More importantly, its relationship with India is marked by an extraordinary degree of

historical, cultural, and economic interdependence that has evolved over centuries.

According to him, Nepal remains deeply connected to India in ways that extend far beyond formal diplomacy.

Geography itself, he argues, gives India a natural advantage.

The open border between the two countries, extensive trade networks, shared cultural traditions, and centuries-old people-to-people ties make India an indispensable partner for Nepal. Millions of Nepalis live and work in India, and countless families share social and cultural relationships across the border.

Economically and logistically, Nepal's dependence on India continues to be far greater than on China.

"The realities of geography cannot be ignored," Pangtey ji observes.

In contrast, the historical circumstances of Tibet were entirely different. Following its incorporation into China, Tibet gradually became heavily dependent on Chinese political, economic, and administrative structures.

The two situations, therefore, cannot be viewed through the same lens.

Nevertheless, Pangtey ji acknowledges that both Nepal and Tibet have often been perceived in geopolitical terms as buffer regions between two major Asian powers: India and China.

Throughout history, he notes, China has consistently sought to strengthen its presence in these buffer areas as part of its broader strategic interests in the Himalayan region.

The Himalaya has increasingly emerged as a zone of geopolitical significance, where infrastructure, connectivity, trade routes, and political influence have become important instruments of statecraft.

Yet, despite China's growing engagement with Nepal, Pangtey ji remains convinced that a Tibet-like scenario in Nepal is highly improbable.

The reasons, he explains, lie in geography, economics, and human relationships.

Nepal's societal links with India are exceptionally deep and enduring. The open border facilitates an ease of movement and interaction that is unique in international relations. Furthermore, the mountainous terrain between Nepal and China poses significant logistical challenges, unlike Nepal's relatively easy access to India through the plains.

> **"China may seek influence in Nepal, but Nepal's deep-rooted historical, cultural, and economic interdependence with India makes a Tibet-like situation highly unlikely."**
>
> *— Surendra Singh Pangtey*

For Pangtey ji, India's strength in the Himalayan region is not derived solely from strategic considerations or military capabilities. It is rooted in something much deeper, its civilizational and economic foundations.

He points out that the fertile plains of northern India, the productive Himalayan regions, and the country's agricultural abundance have historically made India a source of sustenance and stability for its neighbours.

For centuries, India has served as a natural economic partner for the Himalayan states and communities. Trade, food security, cultural exchange, and human mobility have all contributed to this relationship.

"Agriculture has long been one of India's greatest strengths," he says, "and it continues to remain a vital pillar of its resilience and influence in the region."

Listening to Pangtey ji, one realizes that geopolitics in the Himalaya cannot be understood solely in terms of strategic competition between nations. Geography, culture, economics, and historical memory often exert a far greater influence than temporary political developments.

While China's presence in Nepal may continue to grow and regional equations may continue to evolve, Pangtey ji believes that the fundamental realities that bind Nepal to India remain remarkably strong.

The Himalaya, after all, has always been shaped not merely by the ambitions of states but by the enduring connections between its people, landscapes, and civilizations. It is these deeper forces, he suggests, that make a Tibet-like future for Nepal highly improbable and continue to define the unique character of India-Nepal relations in an increasingly complex geopolitical era.

The Himalaya beyond Geopolitics

As our conversation with Shri Surendra Singh Pangtey drew to a close, it became evident that we had traversed much more than contemporary political debates. The discussion had, in many ways, become a journey through the changing landscapes of the Himalaya from the bustling caravan routes of Indo-Tibetan trade and the memories of a connected mountain world to the strategic questions shaping Nepal and the broader Himalayan region today.

Listening to Pangtey ji, one is reminded that the Himalaya was not always perceived through the language of borders, security, and geopolitical competition. There was a time when these mountains functioned as corridors of exchange and interaction. The memories he so vividly recounts of Tibetan traders arriving in Munsyari with salt and wool, and of Indian merchants carrying wheat, mandua, cotton, jaggery, and textiles across high mountain passes evoke an era when the Himalaya was a vibrant civilizational space, animated by trade, trust, and human relationships.

The mountains connected rather than separated. Trade routes became channels through which not only goods but also ideas, customs, languages, and traditions travelled. Communities on either side of the Himalaya developed relationships of mutual dependence and cultural intimacy that transcended political boundaries.

Yet, as Pangtey ji's reflections reveal, the contemporary Himalaya is witnessing a new reality. The region has emerged as a space of growing geopolitical significance, attracting the strategic attention of regional and global powers. Diplomatic equations continue to evolve, and external actors increasingly seek influence in the Himalayan states.

However, his observations on Nepal underscore an important truth: despite changing political circumstances, the relationship between India and Nepal cannot be understood merely through the prism of strategic interests or contemporary geopolitics.

For Pangtey ji, the foundations of India-Nepal relations lie much deeper.

They are shaped by geography, sustained by economic interdependence, strengthened by cultural and religious affinities, and above all, rooted in a shared civilizational heritage that has endured for centuries.

> **"India and Nepal are not merely neighbours; they are bound by geography, culture, history, and an enduring civilizational relationship."**
>
> *— Surendra Singh Pangtey*

History, he believes, offers an important lesson for the present.

Political narratives may shift. Governments may change. New strategic partnerships and geopolitical equations may emerge. Yet the human connections forged across the Himalaya over centuries possess a remarkable resilience. The bonds created through trade, pilgrimage, shared faith, and cultural exchange have repeatedly demonstrated an ability to transcend temporary political disagreements and changing international circumstances.

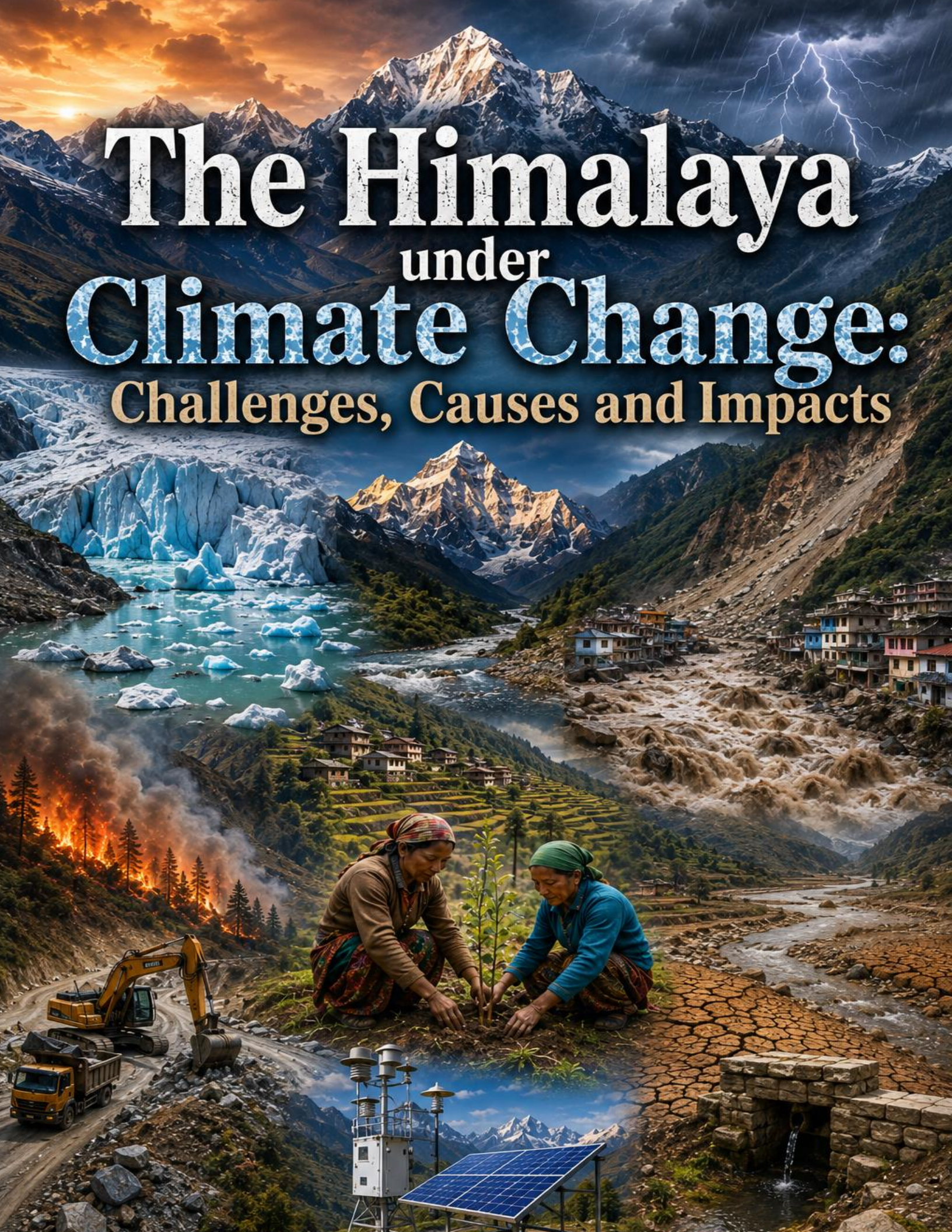
In many ways, Pangtey ji's reflections invite us to reconsider how we perceive the Himalaya itself.

The region is not merely a geopolitical frontier or a buffer zone between competing powers. It is a living civilizational landscape shaped by centuries of interaction, memory, and shared experiences. Understanding its future therefore requires an appreciation of its past—its caravan routes, its border communities, its cultural exchanges, and the enduring relationships that have long defined life in the mountains.

As the Himalaya enters a new era of strategic significance, marked by shifting alliances and intensifying geopolitical competition, his words serve as a timely reminder that sustainable peace and cooperation in the region cannot be built solely on strategic calculations. They must also be informed by historical understanding and a recognition of the deep human connections that continue to bind its peoples together.

In the final analysis, the story of the Himalaya is not simply a story of borders, territories, and geopolitical contests.

It is, above all, **a story of interconnected peoples, shared memories, and common destinies, a story that continues to unfold in the shadow of the world's highest mountains.**


The Himalaya
under
Climate Change:
Challenges, Causes and Impacts

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II.

THE HIMALAYA UNDER CLIMATE CHANGE: CHALLENGES, CAUSES AND IMPACTS

*Prof. **Vishwambhar Prasad Sati***
Senior Professor, Geography and Resource Management, and Dean, School of Earth Sciences and NRM,
Mizoram University

This study examines climate change and its impact on the Himalayan region. It further describes the challenges, causes, and effects of climate change. This is a review paper based on available literature as well as the author's personal observations. The Himalayan region is highly vulnerable to climate change. The study finds that agriculture is declining, snow cover is decreasing, glaciers are melting, valleys and middle altitudes are warming, the intensity and frequency of natural disasters are increasing, and agro-ecological zones are changing. It suggests that climate-smart agriculture, the use of technology, and the reduction of anthropogenic activities can help mitigate climate change.
Keywords: Climate variability; Climate change; Melting glaciers; Extreme hazards; Technology.

Introduction

The Himalaya, a young fold mountain system, is the tallest and one of the youngest mountain ranges in the world. It extends for about 2,500 km from the Pamir Knot in the northwest to the Arakan Yoma mountain ranges of Myanmar in the southeast. Geographically, the Himalaya is divided into three major horizontal divisions: the Western Himalaya, which includes Jammu and Kashmir, Himachal Pradesh, and Uttarakhand; the Central Himalaya, comprising Nepal; and the Eastern Himalaya, which includes Sikkim, Bhutan, and Arunachal Pradesh. In addition to these divisions, there is another important division known as the Eastern Extension of the Himalaya, which includes the hills of Assam, West Bengal, Meghalaya, Nagaland, Manipur, Mizoram, and the hilly parts of Tripura. In terms of vertical divisions, the Himalaya consists of six distinct zones: the river valleys and Shivalik Ranges, the Lesser Himalaya, the Middle Himalaya, the High Himalaya, the Greater Himalaya, and the Trans-Himalaya. These vertical and horizontal divisions together create magnificent and panoramic landscapes across the region.

The climate of the Himalaya varies significantly according to altitude, ranging from sub-tropical conditions in the river valleys to temperate, cold, and extremely frigid conditions in the higher mountain regions. Climatic conditions also change with the seasons. Winters are extremely cold in the middle and high-

altitude regions due to heavy snowfall (Singh & Schickhoff, 2020), while the Lesser Himalaya and river valleys experience comparatively moderate temperatures. In contrast, during the summer season, the middle and higher altitudes remain pleasant and cool, whereas the river valleys and the Shivalik Hills become hot and humid. Heavy rainfall occurs during the monsoon season, which often inundates rivers and leads to flooding in the valleys. The monsoon rains also trigger landslides and mass wasting in many mountainous areas. Humidity generally remains high during both the winter and monsoon seasons.

Forests in the Himalayan region are distributed according to variations in altitude and climate. In the valley regions below 800 meters, sub-tropical monsoon deciduous forests are commonly found. Above these regions, pine forests are distributed between 800 and 1,600 meters. Mixed oak forests occur between 1,600 and 2,200 meters, while coniferous forests are found between 2,200 and 2,800 meters. Beyond 2,800 meters and up to the snowline, alpine meadows dominate the landscape (FSI, 2021). Due to the wide range of climatic and altitudinal conditions, the Himalayan region possesses exceptionally rich biodiversity and supports a variety of flora and fauna (Rasul et al., 2019).

Agriculture is widely practiced throughout the Himalayan region and is characterized by rich agro-biodiversity. Different crops are cultivated according to variations in altitude, climate, and soil conditions. Paddy and wheat are mainly grown in the river valleys, while millets, pulses, and oilseeds are cultivated in the middle and high-altitude regions. Similarly, a variety of fruits are grown in different climatic zones. Mango, guava, and papaya are commonly cultivated in the valleys, whereas citrus fruits are mainly grown in the middle altitudes. In the higher altitudes, temperate fruits such as apple, pear, peach, plum, apricot, walnut, and almond are extensively cultivated. Among vegetable crops, potatoes are mainly grown in the higher altitudes, onions are cultivated in the lower and middle altitudes, and tomatoes are grown across almost all altitudinal zones of the Himalaya.

This study examines climate change in the Himalaya and its challenges, causes, and impacts and suggests how to mitigate climate change.

Results and Discussion

High Climate Variability and Change

The Himalaya is highly prone to climate change because of its angularity, verticality, and fragility. During the last few decades, high variability in temperature and precipitation has been observed across the Himalayan region. Since the end of the Little Ice Age (1400–1800 AD), temperatures in the Himalaya have increased significantly, accompanied by considerable climatic variability (ICIMOD, 2023; IMD, 2023). Summers have become warmer, while the monsoon

period has shrunk from four months to nearly three months, with increased intensity and frequency of rainfall events. Similarly, the intensity and duration of snowfall have decreased, and the timing of snowfall has also shifted.

A study conducted by the present author reveals that winter precipitation has declined and shifted from January–February to March–April, which are generally considered dry months in the region. Rainfall has also slightly increased during October–December, indicating increasing variability in precipitation patterns. The author further observed that snowfall spells in the middle altitudes during winter have reduced considerably. Notably, the winter of 2025-2026 remained almost snowless across large parts of the Himalayan region.

Due to the increase in temperature, the river valleys and middle altitudes of the Himalaya are warming rapidly (Maharjan & Sherpa, 2026; Singh et al. 2010). Winters are becoming extremely cold, summers excessively hot, droughts more severe, and monsoon rainfall more frequent and intense. These changing climatic conditions are affecting glaciers, water resources, agriculture, biodiversity, and the livelihoods of mountain communities (IPCC, 2021). Recent studies have also reported accelerated glacier retreat, declining snow cover, and increasing climatic uncertainty across the Hindu Kush Himalayan region.

The high Himalayan regions, such as Mukteshwar in the Kumaon Himalaya, have experienced comparatively low humidity, whereas the river valleys and the Doon Valley have been receiving higher humidity levels, in contrast to previous decades. A similar trend has been observed in temperature patterns. High-altitude areas, including Mukteshwar, have also been affected by rising temperatures. The average summer temperature in the Doon Valley, which was around 37°C a few decades ago, has now exceeded 40°C. The 76-km-long Doon Valley, stretching from the Ganga River to the Yamuna River, has increasingly transformed into a concrete-dominated urban landscape, contributing significantly to the rise in temperature.

Causes of Climate Variability and Change

There are numerous causes of increasing climate variability and climate change in the Himalayan region. Among the major factors are the rapid expansion of built-up areas, forest depletion, the development of infrastructure facilities such as road construction and widening, railway line construction, other developmental initiatives, and the rapid growth of mass tourism across the Himalaya (Sati, 2026). Forest degradation has become a serious concern, as dense and moderately dense forest areas are declining, while open forests and scrublands are increasing. Overall, natural forest cover has decreased, although the area under afforestation programmes increased by about 1.4% during the past decade.

The development of infrastructure has also accelerated climate change in the region. Road widening, the construction of new roads, and railway projects have

contributed to environmental degradation and rising temperatures. In addition, mass tourism has increased substantially in the Himalaya, particularly for adventure activities such as mountaineering, river rafting, and trekking. A large number of pilgrims visiting high-altitude pilgrimage centres further contribute to environmental stress and warming. Rapid population growth on the fragile mountain slopes has also intensified the impacts of climate change and environmental degradation.

Impacts of Climate Change in the Himalayan Region

Climate change impacts in the Himalayan region are enormous and multidimensional. They affect almost all spheres of life, including socio-economic conditions, ecological systems, and the occurrence of natural hazards. The production and productivity of crops, both in agriculture and horticulture, have declined significantly over the years. This decline has accelerated out-migration from rural areas as people search for better livelihood opportunities elsewhere. A study reveals that more than 20% of the population has out-migrated from the rural areas of the Uttarakhand Himalaya. Approximately 1,700 villages have turned into ghost villages as a consequence of this large-scale migration. Furthermore, in more than 10% of the villages, the remaining population constitutes less than 10% of the original inhabitants (Sati, 2021). Such demographic changes have resulted in extensive land abandonment across the Himalayan region. Due to the abandonment of agricultural land, natural springs, which traditionally served as the primary sources of drinking water, are drying up rapidly. As arable land has increasingly turned barren, the rate of surface runoff has increased considerably, reducing the infiltration of rainwater into the ground. Consequently, groundwater recharge has declined, leading to acute water scarcity in many parts of the Himalaya.

Many traditional crop races and cultivars have already become extinct, while several others are on the verge of extinction. Some crop varieties have gradually shifted towards higher altitudes in response to changing climatic conditions (Sati & Kumar, 2025). These transformations have caused substantial ecological changes throughout the Himalayan region. Citrus fruits, which were traditionally cultivated at altitudes ranging between 800 and 1,200 meters, have almost completely disappeared from these locations. Similarly, apple cultivation is no longer viable in many parts of the Uttarakhand Himalaya where it was once widely practiced. There has also been a significant decline in the cultivation of traditional crops, particularly millets, which formed the backbone of the mountain agrarian economy and food security system (Sati & Kumar, 2023).

The author has observed that pine trees are increasingly invading the mixed-oak forests due to the warming of river valleys and middle-altitude regions. Pine forests generally thrive in sub-tropical climatic conditions, whereas mixed-oak forests are characteristic of temperate climates. The upward expansion of pine

forests towards higher altitudes indicates a gradual transformation of temperate climatic zones into sub-tropical ones (Sati, 2013). This ecological shift is profoundly altering the biodiversity, vegetation structure, and environmental stability of the Himalayan ecosystems.

A study on thin and thick snow cover revealed that snow cover in the Uttarakhand Himalaya has decreased by nearly 36% during the last three decades. The study further demonstrates that thick snow cover is more vulnerable to climate change than thin snow cover (Surajit et al., 2024). The melting of snow cover has been particularly high in the Alaknanda and Bhagirathi valleys, mainly due to the excessive influx of pilgrims to the high-altitude pilgrimage destinations. In addition, many glaciers, ranging from small to large in size, are receding rapidly across the Himalayan region. Glacier retreat and declining snow cover are significantly affecting river discharge patterns, hydrological regimes, and water availability downstream.

High variability and changes in precipitation patterns have further intensified the occurrence of cloudbursts and glacier-burst-induced disasters, including debris flows, flash floods, landslides, and mass movements. Geohydrological disasters are now occurring with greater frequency and intensity throughout the Himalaya. The author observed that during a short period of only three years (2020–2022), more than 200 disasters occurred in the Uttarakhand Himalaya alone. Some of the prominent geohydrological disasters in the region include the Rishi and Dhauli Ganga calamity in 2021, the Uttarkashi disaster in 2022, and the Bandal Valley catastrophe in 2023 (Sati, 2024; 2022). In addition to these disasters, forest fires have become increasingly frequent and severe every year. The spatial extent of forest fires is expanding, and their occurrence is gradually shifting towards higher altitudes as temperatures continue to rise (Sati, 2024). These environmental changes collectively indicate that the Himalayan region is highly vulnerable to climate change and its associated ecological and socio-economic consequences.

Conclusion

This study reveals that the Himalaya is facing significant impacts of climate variability and change in almost all aspects. Agriculture is declining, agro-climatic zones are shifting to higher altitudes, snow is melting, river valleys and middle altitudes are warming, geohydrological disasters are becoming more frequent and intense, forest fires are spreading towards higher altitudes, and natural springs are drying up. These changes are leading to a higher rate of out-migration. There is a vital need to frame and implement climate-resilient policies. Climate-smart agriculture, afforestation, control over the expansion of infrastructural development projects, and the use of appropriate technology can help mitigate the climate crisis in the Himalaya.

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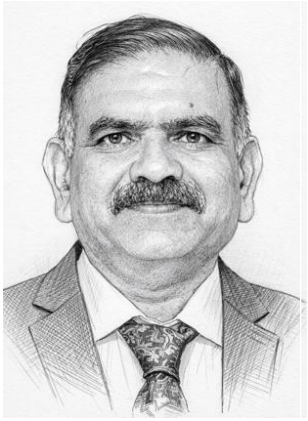

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Climate Change and Food Security in the Indian Himalaya:

Challenges and Adaptation

III.

CLIMATE CHANGE AND FOOD SECURITY IN THE INDIAN HIMALAYA: CHALLENGES AND ADAPTATION

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The Indian Himalayan Region, stretching from Jammu & Kashmir to Arunachal Pradesh, is warming at a pace faster than that of the world due to global warming and is becoming a focus area in the growing food security concerns. The processes of elevation-based warming, a shrinking cryosphere, and erratic monsoon and winter rainfall patterns have contributed to decreased agricultural productivity, shortage of water for irrigation and drinking purposes, and climate-induced hazards such as GLOFs, flash flooding, and landslides.

The two most significant reports that were published by ICIMOD in 2026 include the HKH Glacier Outlook 2026 and HKH Snow Update 2026. Both studies reveal that there was a doubling of glacial ice loss in the Hindu Kush Himalaya region since 2000 and that the snow persistence in 2026 is at its lowest in more than two decades, with ten of twelve main river basins experiencing below-average snow. These concerns are in line with those raised in the AR6 and SROCC of the IPCC, which identified the Himalayan mountain ecosystem as one that was "uniquely vulnerable" to climate change. This report compiles recent developments on the relationship between climate and food security in the Indian Himalayas. In this report, issues related to state-level institutional shortcomings in Uttarakhand, Himachal Pradesh, Sikkim, and the North-Eastern Himalayas have been discussed. The report outlines a matrix for adaptive measures in terms of policy, water security, agriculture, disaster risk reduction, livelihood, and climate financing.

Approximately 50 million people reside in the Indian Himalayan Region, along with a range of wildlife and vegetation that directly help in ensuring water security, food security, and energy security of millions living in the Indo-Gangetic and Brahmaputra plains. The wider region of HKH, which is known as the “Third Pole” and the “Water Tower of Asia,” has the largest ice deposit outside the Polar Regions and supplies water to ten major river basins like Indus, Ganga, and Brahmaputra. The agricultural activities in IHR are based on smallholder and rain-fed agriculture using terraces, which have very limited irrigation facilities. This makes agriculture in the mountains highly vulnerable to climate change effects.

The Indian Himalayan Region: Context and Vulnerability

The IHR includes 11 states/UTs including Jammu & Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Meghalaya, Mizoram, Tripura, as well as the hill districts of Assam and West Bengal. Vulnerability of IHR is a result of:

1. Altitude-based warming: while 1˚C increase in global temperature causes an increase of 1.5-2˚C in high altitudes, resulting in adverse effects at river headwaters.
2. Slopes and fragile geography are vulnerable to landslides, soil erosion, and slope instability, exacerbated by uncontrolled infrastructure development.
3. Dependence on natural springs as a source of drinking water and irrigation; 10% of the springs were dried up in some parts of Uttarakhand in the last decade.
4. Predominantly subsistence agriculture dependent on rains, with low levels of market linkages, storage and irrigation.
5. Insufficient data regarding glaciers; areas such as Sikkim and Zanskar poorly monitored.

Climate Change: Future Projections (IPCC Assessments Report)

According to the IPCC's AR6 Synthesis Report (2023), "even very-low-emission pathways may see global warming exceed 1.5 ˚C this century" and increase food insecurity, extreme events, and displacement. Mountain ecosystems are affected irreversibly due to glacial retreat and permafrost thawing. In its 2019 SROCC report, "HKH regions would warm by more than 2˚C on average and up to 3.5-6 ˚C for glaciated river basins in the HKH under 1.5˚C warming pathway by 2100."

As of June 2026, the IPCC's Seventh Assessment cycle commenced in June 2023; however, no AR7 Working Group reports or synthesis reports have been published at this time. This means that, for the most part, the most recent IPCC findings on the Himalayas are those from AR6:

River Basin	Share of HKH Glacier Area	Glacier Area Lost (1990-2020)
Indus	44%	6%
Ganga	13%	21%
Brahmaputra	20%	16%
Karakoram	—	2% (“Karakoram Anomaly”)

Table 1: *Glacier area loss by major river basin, 1990–2020 (Source: ICIMOD, HKH Glacier Outlook 2026 / Changing Dynamics of Glaciers in the HKH Region, March 2026).*

Variations in Precipitation and Extreme Weather

Other than the cryosphere, there have been variations in the starting and ending times of the monsoon season, increased intense precipitation events, and an increase in cloudburst-related flash flooding and landslides in the IHR. Examples of recent GLOFs include those in 2021 in Chamoli, 2023 in South Lhonak Lake (Sikkim) where 270 million cubic meters of water and sediment were released, causing deaths of more than 90 people and the destruction of the 1,200 MW Teesta-III hydroelectric power plant, and the 2025 Dharali disaster in Uttarakhand.

Impacts of Climate Change on Food Security in the Himalayas

A systematic review of household food security studies in the Himalayas identified reduced crop productivity (79%), livestock impacts (40%), and disruptions to food supply chains (29%) as the primary pathways through which climate change threatens food security. These impacts affect all four dimensions of food security: availability, access, utilisation, and stability.

Food Availability

Climate change has reduced agricultural productivity through altered growing seasons, erratic rainfall, and increased pest and disease incidence. Declining spring and glacier-fed water resources have constrained irrigation, particularly during the pre-monsoon period. Livestock production is affected by heat stress, fodder shortages, and emerging diseases. In addition, warming winters and reduced chilling hours have decreased apple productivity and shifted suitable cultivation zones to higher elevations.

Food Access

Extreme weather events, including landslides, flash floods, and cloudbursts, frequently disrupt transportation and market access in remote Himalayan regions, limiting food availability. Crop and livestock losses reduce household incomes and purchasing power, while climate-induced out-migration increases women's agricultural workload, constraining adaptive capacity.

Food Utilization

Reduced water availability and declining water quality adversely affect food preparation, sanitation, and nutritional health. Furthermore, the replacement of traditional, nutrient-rich crops such as millets, buckwheat, and indigenous pulses with a narrower range of commercial and staple crops has reduced dietary diversity in many mountain communities.

Food Stability

The increasing frequency of extreme climatic events, including Glacial Lake Outburst Floods (GLOFs), flash floods, landslides, and cloudbursts, has intensified disruptions to agricultural production and food supply systems. Long-term glacier retreat and declining snowpack further threaten the reliability of irrigation water, increasing the vulnerability of mountain agriculture.

Model projections for the Ganga Basin indicate that a 21% reduction in glacier area could significantly reduce irrigation water availability, threatening the food security of over 400 million people dependent on Indo-Gangetic agriculture. These findings demonstrate that climate-induced changes in the Himalayan cryosphere have far-reaching implications for both regional and national food security.

Effects on Food Security

A systematic review of studies of the effects of climate change on food security of the households in the Himalayas has indicated that low crop production (in 79% of the studies reviewed), effects on livestock (in 40% of the studies), and disturbances in the food supply chain (in 29% of the studies) are the main ways through which food availability is being affected by climate change. These effects affect all four pillars of food security: Precipitation Variability and Extreme Events

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Challenges in the Indian Himalayas Uttarakhand

Uttarakhand presents common challenges to IHR as the models predict warming of 1.3-1.6 degrees centigrade by mid-century and about 10% of the spring sources have dried over the last decade. Rain-fed hill farming in the state is mainly subsistence farming characterized by small holdings with low inputs and market access, coupled with a trend of migration from the agriculture sector.

Himachal Pradesh

Temperate horticulture with emphasis on apple production that requires specific winter chilling units is the mainstay of agriculture in Himachal Pradesh. Warmer conditions are gradually forcing apple cultivation further up making it difficult for mid-hill farmers to earn a living from the crop. The Climate Change Cell of Himachal Pradesh is in phase II and pilot projects for QR coding bio-inputs for tracing and support climate resilient horticulture.

Sikkim and the Eastern Himalaya:

Sikkim is located in a part of HKH with many glaciers but poorly monitored. The GLOF at South Lhonak Lake in 2023 demonstrated disaster risks of region due to exposure of hydropower and Agriculture infrastructure to glacial lake dynamics. Fully organic farming policy of Sikkim is complimenting their climate resilient agriculture and biodiversity based livelihoods policies.

North-Eastern Himalayan States

Arunachal Pradesh, Nagaland, Manipur, Meghalaya, Mizoram, and Tripura face problems of changing monsoon pattern, high dependence of biodiversity for food and livelihoods (about 85% of mountain population dependent on local biodiversity) and less infrastructure for climate adaption than Western Himalaya, though State Climate Change Cells are working in these states.

Adaptation Strategies: Building a Climate-Resilient Himalaya

Climate change is already affecting farming and food security in the Indian Himalayas. To tackle these challenges, the Government of India, state governments, research institutions, and local communities are working together to develop practical solutions. Programmes such as the **National Mission on Himalayan Studies (NMHS)** have supported hundreds of research and development projects across the Himalayan region. In 2026, the **Him-CONNECT** platform showcased several innovative technologies for water conservation, climate-smart farming, and renewable energy developed by leading institutions such as IIT Roorkee, IIT Mandi, and the G.B. Pant National Institute of Himalayan Environment.

Strengthening Water Security

Water is becoming increasingly scarce in many Himalayan villages as springs dry up and rainfall patterns become unpredictable. To address this, efforts are being made to restore natural springs by protecting their recharge areas and managing water at the watershed level. Programmes like the **Indian Himalayas Climate Adaptation Programme (IHCAP)** also support early warning systems and help communities adopt alternative livelihood options during climate-related crises.

Promoting Climate-Resilient Agriculture

Farmers are being encouraged to grow traditional crops such as millets, buckwheat, and local pulses because they can better withstand drought, frost, and changing weather conditions. Expanding high-value crops and off-season vegetables is also helping improve farmers' incomes. Digital weather advisories, improved seeds, and support from Farmer Producer Organisations (FPOs) and **Digital Sakhis** are enabling small farmers to make better farming decisions and adopt modern agricultural practices.

Reducing Disaster Risks

Frequent disasters such as glacial lake outburst floods (GLOFs), flash floods, and landslides highlight the need for better disaster preparedness. Authorities are strengthening glacier and glacial lake monitoring systems and developing early warning systems to protect vulnerable communities. There is also greater emphasis on carefully assessing hydropower and infrastructure projects in high-risk mountain areas. Expanding glacier and snow monitoring, especially in regions like Sikkim, Zanskar, and the Karakoram, will improve disaster forecasting and water resource planning.

Livelihood Diversification and Financial Support

Climate change has made farming in the Himalayan region more uncertain due to unpredictable rainfall and frequent natural disasters. To reduce farmers' financial losses, the government is promoting **weather-based crop insurance,** supported by satellite technology, under schemes such as the **Pradhan Mantri Fasal Bima Yojana (PMFBY).** These schemes help farmers receive compensation more quickly after crop damage. At the same time, farmers are encouraged to earn income from different sources instead of depending only on traditional farming. Activities such as **off-season fruit and vegetable cultivation, Agri-tourism, beekeeping, handicrafts, and other small rural businesses** can provide additional income and make mountain communities more resilient to climate change.

Recommendations:

1. Increase monitoring of glaciers and snow in regions with less data collection, such as Sikkim, Zanskar, and Karakoram, as it will make warning signals and water plans more accurate.
2. Consider spring sheds and micro-watersheds rather than administrative watersheds as the main unit in the water security plan.
3. Introduce climate-resilient and nutritionally diversified traditional crops (millets, buckwheat, and pulses) into state agriculture policy and procurement in order to increase food security and diversity of nutrition.

4. Implement GLOF and flash-flood early-warning systems in all IHR states, along with mandatory hazard assessments of hydroelectric and other projects in glacier catchment areas.
5. Provide parametric insurance based on satellites in smallholders' hill farms, with quick pay-out mechanisms connected to PMFBY.
6. Mobilize dedicated funding for adaptation and mitigation in the Himalayas: domestic and foreign to cover the $102 billion gap in adaptation-mitigation spending.
7. Develop market connections, cold storage and supply chain management for off-season horticulture in mountains, transforming short periods of cultivation into an economic advantage.
8. Combine traditional and indigenous knowledge about the climate with scientific climate services, answering criticism of inadequate consideration of social sciences in Himalayan climate knowledge creation.

The Indian Himalaya has been termed a “breaking point” in cryosphere stability, with cascading consequences for food security that extend far beyond the mountains themselves to the food and water security of over 400 million people across the Indo-Gangetic plains. Climate change poses a significant and growing threat to food security in the Indian Himalayan Region (IHR) by accelerating glacier retreat, reducing snow cover, altering precipitation patterns, and increasing the frequency of extreme weather events. These changes adversely affect agricultural productivity, water availability, livestock, and rural livelihoods, undermining all four dimensions of food security-availability, access, utilisation, and stability. Given the strategic importance of the Himalayas as the source of major river systems supporting millions of people downstream, the impacts extend well beyond the mountain communities. Although India has initiated several adaptation measures through national missions, state action plans, and community-based interventions, existing efforts need to be strengthened and scaled up to match the accelerating pace of climate change. Future strategies should emphasize climate-resilient agriculture, integrated water resource management, enhanced glacier and snow monitoring, disaster risk reduction, livelihood diversification, and the integration of indigenous knowledge with scientific research. A coordinated, well-funded, and evidence-based approach involving governments, research institutions, local communities, and development partners is essential to enhance resilience and ensure sustainable food and water security in the Indian Himalayas.

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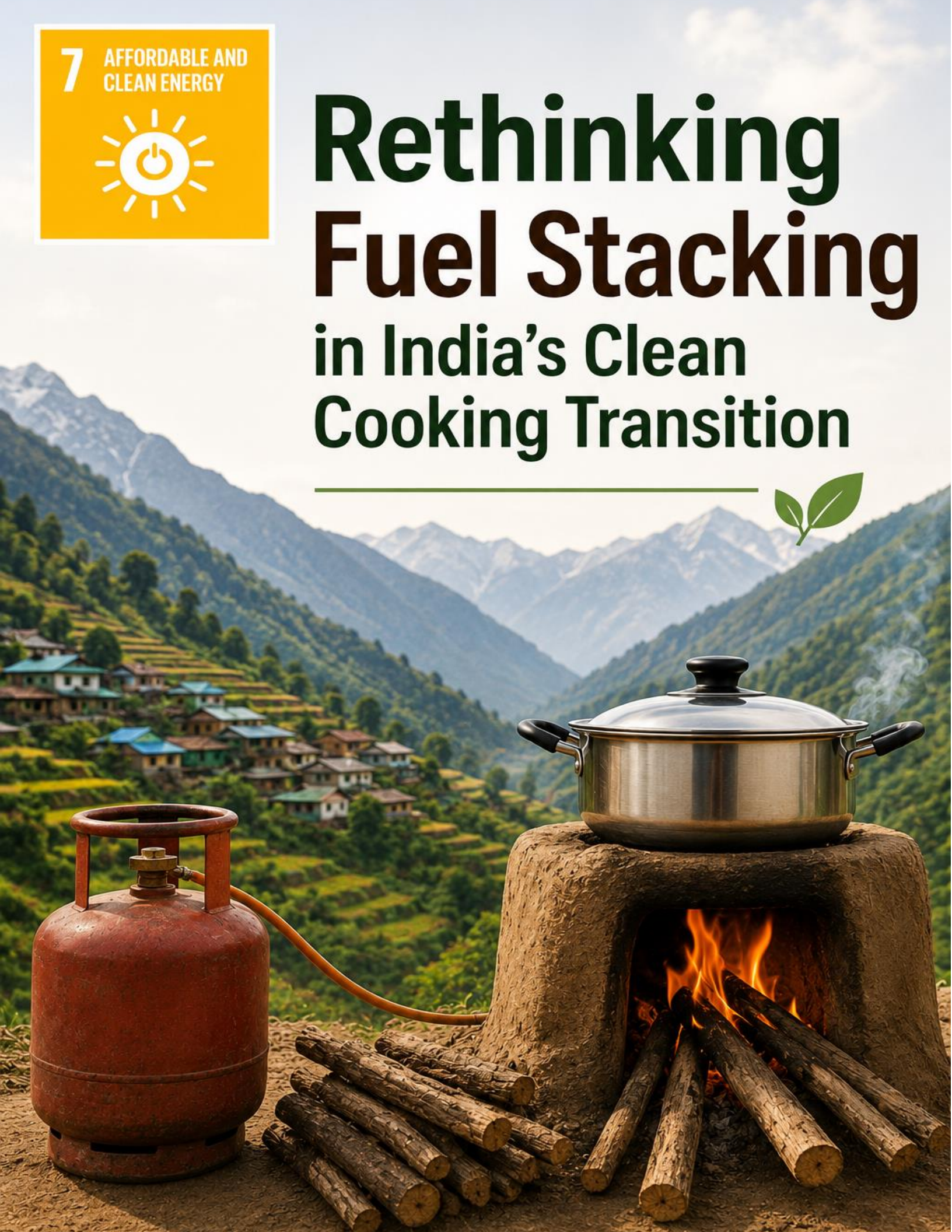
7 AFFORDABLE AND CLEAN ENERGY

Rethinking Fuel Stacking in India's Clean Cooking Transition



IV.
Rethinking Fuel Stacking in India's Clean Cooking Transition

Shelja
PhD scholar at the Indian Institute of Technology Madras

Over the past decade, in line with the goal of universal access under Sustainable Development Goal 7, the Government of India has made significant progress in expanding the adoption of clean cooking fuels, particularly Liquefied Petroleum Gas (LPG). Policies such as the Pradhan Mantri Ujjwala Yojana (PMUY) and Pratyaksh Hanstantrit Labh (PAHAL) have played a central role in rapidly increasing LPG access. At present, the initiatives to expand the network of Piped Natural Gas (PNG) are also in action.

The harmful effects of using traditional or solid fuels like firewood, crop residue, and charcoal are not limited to indoor air pollution and climate change. Reliance on traditional fuels has also been associated with adverse outcomes for health, education, and overall human development. Thus, it is an important sphere for improvement for sustainable development.

According to the Household Consumption Expenditure Survey (HCES) 2023-24, about 61.54 percent of households in India primarily rely on LPG for cooking.

Yet, the transition to clean cooking remains incomplete. While 35.94 percent of households have fully transitioned to LPG, 44.74 percent continue to practice fuel stacking, using LPG alongside traditional fuels to meet their energy needs. The persistence of fuel stacking indicates that widespread LPG adoption has not entirely displaced traditional fuels, with households continuing to diversify their fuel use to manage costs, preferences and energy security concerns. Firewood remains particularly important in rural areas, where it is often readily available at little or no monetary cost. In addition, cultural practices and long-standing cooking preferences continue to influence fuel choices, creating barriers to the exclusive use of clean cooking fuels.

Success in the Mountains

The success of India's clean cooking transition is particularly evident in several mountainous states. In Jammu & Kashmir, 72.83 percent of households primarily use LPG, while Uttarakhand records 68.71 percent.

The transition has been even more remarkable in the Northeast, where LPG serves as the primary cooking fuel for 82.88 percent of households in Manipur and an impressive 96.39 percent in Mizoram.

These figures are particularly noteworthy given the difficult terrain, dispersed settlements, and continued availability of traditional biomass fuels in many of these regions. State-specific initiatives such as the Mukhyamantri Antyodaya Free Gas Refill Yojana in Uttarakhand and the Mukhya Mantri Grahini Suvidha Yojana in Himachal Pradesh have further accelerated adoption by addressing local barriers and improving affordability.

The colder climatic conditions of these states also influence household fuel choices, as firewood provides a combination of cooking energy and space heating that LPG alone cannot readily offer. These figures highlight the remarkable success of clean cooking programmes in reaching geographically challenging regions and expanding access to LPG in remote mountain communities. Yet access alone does not guarantee energy security.

When Energy Security Is Disrupted

Worldwide, many countries are facing challenges relating to energy commodities and services due to ongoing geopolitical tensions in West Asia, disruptions in global supply chains, and the resulting uncertainty in energy markets. The issues in India range from emerging black markets to hindrance in the functioning of midday meal schemes. The market has witnessed a rise in demand for induction stoves, especially in urban areas. These manifestations have taken a different shape in the Himalayan states.

The Himalayan Experience

The impacts have been particularly severe in the Himalayan region, where local economies are heavily dependent on tourism and small service-sector businesses. While the challenges faced by households have received considerable attention in public and political discussions, the vulnerabilities of businesses dependent on LPG have remained relatively overlooked.

Reports from the region suggest that restaurants, roadside eateries and tourism-dependent enterprises faced significant disruptions, forcing some to reduce services, alter menus, temporarily suspend operations or seek alternative fuel sources. Among the most visible examples were the familiar Pahadi Maggi stalls that dot mountain roads and tourist destinations, many of which struggled to maintain regular operations during the disruption. Unlike urban centres in the plains, where induction cooking emerged as a viable alternative, concerns regarding the reliability of electricity supply limited such transitions in many

mountain regions. At the same time, the PNG network remains relatively underdeveloped in these areas, restricting access to alternative clean cooking fuels.

Fuel Stacking as Resilience

The disruption revealed an important feature of energy use in mountain regions. The continued availability of forests allowed many households and businesses to fall back on traditional fuels when LPG became difficult to access or afford. While this reduced the immediate impact of the disruption on households, the transition was far less straightforward for restaurants, hotels and other tourism-dependent businesses whose operations had become increasingly dependent on LPG-based infrastructure and supply chains. The experience highlights a trade-off often overlooked in clean cooking debates. The persistence of traditional fuels, frequently viewed as evidence of an incomplete energy transition, also provided a degree of resilience during a period of energy insecurity. At the same time, prolonged reliance on firewood is neither a sustainable nor a desirable long-term solution, as it can place additional pressure on local forest ecosystems and erode some of the environmental gains achieved through clean cooking programmes.

Beyond Access: The Next Policy Challenge

The experience carries important lessons for a country as geographically, economically and culturally diverse as India. It has also challenged conventional perceptions of fuel stacking, which is often viewed solely as a sign of energy poverty or an incomplete transition. In the face of supply disruptions, maintaining access to multiple fuel sources emerged as a resilience strategy that enabled households to continue meeting their energy needs. Future energy policies need to focus on building robust infrastructure capable of supporting diverse fuel sources while recognizing that household energy needs vary not only by income but also by geography.

The crisis also highlighted that commercial LPG consumers received far less attention in policy discussions than domestic consumers, despite facing significant operational disruptions. Future policy frameworks should therefore aim to improve the resilience of both households and businesses to energy shocks.

The growing shift towards electricity as a cooking fuel also raises concerns about deepening inequalities. While some households are able to move to cleaner alternatives, many continue to face affordability constraints even with LPG subsidies. Without careful policy design, the transition to cleaner energy sources risks becoming uneven, reinforcing existing socio-economic disparities.

The crisis revealed that while access to clean cooking fuels is essential, resilience lies in the ability of households and businesses to adapt when those fuels become unavailable or unaffordable. India's clean cooking transition has undoubtedly been one of the country's major development successes. Yet the recent disruptions demonstrate that the next phase of policy must move beyond access towards resilience. Ensuring that households and businesses have reliable, affordable and regionally appropriate energy options will be crucial for safeguarding both energy security and the gains achieved under SDG-7.

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India's AI Revolution:

Opportunities, Challenges, and the Road to Digital Sovereignty

V.

India's AI Revolution:

Opportunities, Challenges, and the Road to Digital Sovereignty

Dr Anil Pise

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In February 2026, at the India AI Impact Summit in New Delhi, the government announced it would push national compute capacity past 38,000 GPUs, with a stated target of 100,000 public GPUs by the end of the year. It was a small number by the standards of the hyperscalers in Virginia or Iowa, but a telling one for India: a country of 1.4 billion people, generating an outsized share of the world's data and digital transactions, was for the first time treating computing infrastructure the way it once treated steel plants and dams as a strategic asset to be built at home, not rented from abroad.

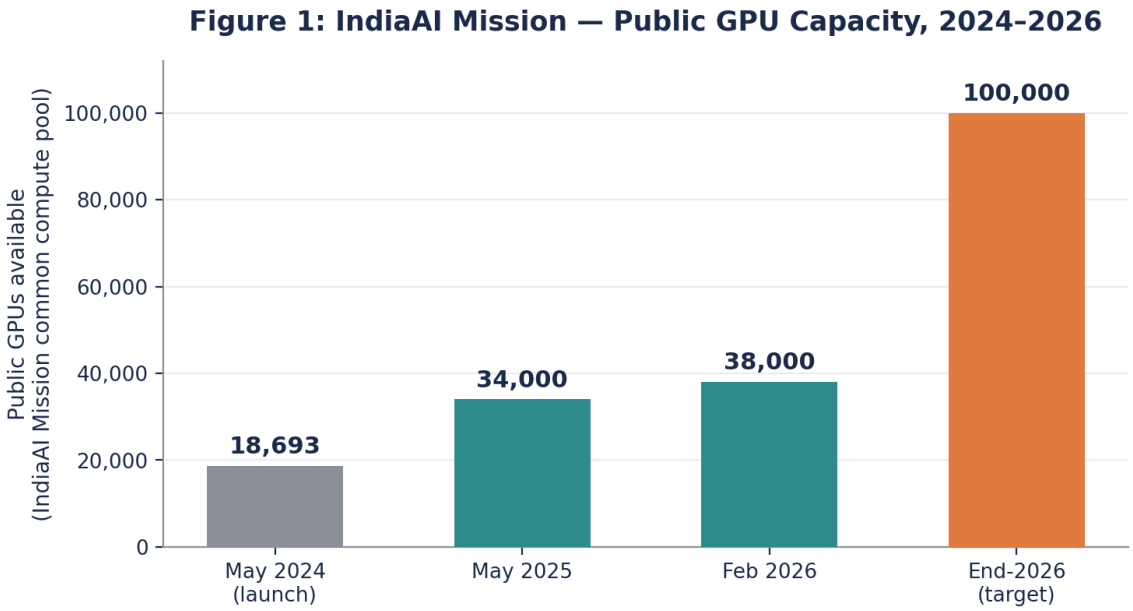
That tension between India's scale and its dependence is the real story of the country's AI moment. The headlines write themselves: India has the world's largest base of AI-related developer activity on GitHub, a thriving startup ecosystem, and a government willing to spend real money on sovereign infrastructure. But scratch the surface, and the picture is less triumphant. India designs almost none of the chips its AI runs on, trains almost none of its foundation models from scratch at frontier scale, and is only now writing the data-protection rules that will govern how AI systems use the personal information of over a billion citizens. "AI revolution" is the comfortable phrase. "AI dependency, with sovereignty as an aspiration" is the more accurate one, and the gap between those two framings is what this article tries to map.

The Opportunity: Scale as a Strategic Asset

India's advantage in AI was never going to come from inventing transformer architectures. It comes from three things money cannot buy quickly: scale, talent, and the Digital Public Infrastructure (DPI) stack built over the past decade.

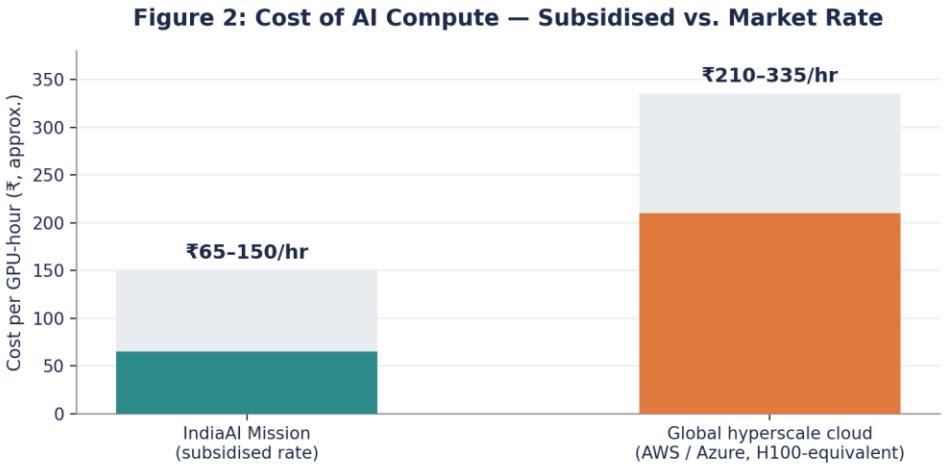
- **Digital Public Infrastructure as AI fuel.** Aadhaar, UPI, and the broader India Stack gave the country something most economies lack: a population already comfortable transacting digitally, generating structured data at a volume few other markets can match. UPI alone processes more transactions monthly than several G7 payment networks combined. That data exhaust, if governed well, is a genuine comparative advantage for training models on real-world Indian behaviour rather than scraped, English-dominant internet text.

- **A government willing to subsidise compute.** The IndiaAI Mission, approved in March 2024 with an outlay of roughly ₹10,372 crore (about $1.2 billion) over five years, has gone from announcement to actual GPUs in data centers faster than most government technology programmes manage. By mid-2026, around 34,000–38,000 GPUs were live across facilities in Chennai and other centers, offered to startups, researchers, and government agencies at roughly ₹65–150 per GPU-hour, well below the $2.50–4.00 per hour that comparable H100 capacity costs on AWS or Azure. Sarvam AI, selected as the lead startup under the Mission's foundation-model pillar, released open-source models in February 2026, including a mixture-of-experts model and a larger architecture activating roughly 9 billion parameters per token. Three more startups have since been chosen to build India-specific foundation models, and over 350 datasets have been uploaded to AI Kosh, the Mission's open-data repository.



Source: PIB, EE Times, IndiaAI Mission press briefings (Feb 2026). End-2026 figure is a stated government target, not an achieved figure.

Figure 1: IndiaAI Mission public GPU capacity growth, 2024-2026



Source: IndiaAI Mission empanelment rates vs. published AWS/Azure H100 cloud pricing, as reported mid-2026. Figures are approximate and currency/market-dependent.

Figure 2: Cost of AI compute, subsidised vs market rate

The gap between those two figures is the entire argument for the subsidy: it is the difference between AI compute being a privilege of well-funded labs and AI compute being something a five-person Bengaluru startup can actually afford to experiment with.

Talent and the "reverse brain drain" bet. India trains more engineers annually than any country bar China, and its diaspora occupies senior AI roles at nearly every major American lab. The government's explicit hope voiced repeatedly by IT minister Ashwini Vaishnaw is that cheap domestic compute and growing startup funding will pull some of that talent back, or at least let it build for Indian problems without relocating. Early evidence is mixed but not negligible: Indian AI startups raised meaningfully more capital in 2025–26 than in the two years prior, concentrated in agentic enterprise tools, vernacular-language models, and AI applications for healthcare and agriculture.

Sectoral application over frontier research. Where India is genuinely competitive is not in building the next GPT-class model, but in applying existing models to domain problems at population scale: diagnostic triage in under-resourced clinics, crop-disease detection for smallholder farmers, vernacular customer service for a market that speaks twenty-two scheduled languages, and fraud detection layered onto the UPI rail. This is less glamorous than foundation-model headlines, but it is where the actual economic value for a middle-income country is likely to be realized first.

The Challenges: Where the Story Gets Harder

This will fail if India mistakes compute subsidy for compute sovereignty. Every GPU in the India-AI cluster is an NVIDIA part. The Mission's ₹10,372 crore programme is, functionally, a large standing order for an American company's hardware, run on data center real estate India controls but on silicon it does not design or fabricate. That matters because the same legal authority that has progressively cut China off from advanced NVIDIA chips since October 2022 is the authority that, in a different political climate, could constrain India's access too. The interim US–India trade framework finalised in February 2026 includes language intended to protect India's chip access but a trade agreement is not a guarantee, and India's current AI build-out rests on the durability of a bilateral relationship more than on domestic capability.

The compute gap is still enormous in absolute terms. Even at a generous 100,000-GPU target by end-2026, India's public compute pool will be a rounding error next to the hundreds of thousands of GPUs that single American hyperscalers deploy in individual data center campuses. Subsidised access helps a startup train a fine-tuned model; it does not let India train a frontier foundation model independently, and no credible roadmap currently claims it will in the near term.

Semiconductors remain upstream-dependent. India has approved 12–13 semiconductor projects, and the Tata–PSMC fab in Dholera, targeting first silicon by late 2026 at 28nm logic, with capacity for around 50,000 wafers a month is a genuine milestone. Micron's assembly-and-test facility in Sanand became operational in February 2026. But 28nm is several generations behind the leading edge that frontier AI chips require, and the equipment, speciality gases, wafers, and design tools for even these plants are still sourced abroad. The government's own ISM 2.0 framework, launched in the 2026–27 Budget with a ₹1,000 crore allocation on top of an ₹8,000 crore modified scheme, explicitly acknowledges this: the stated goal now is building the upstream ecosystem equipment, materials, full-stack chip design IP, not just assembling more fabs. That is a multi-decade undertaking, not a multi-year one. India's own targets put 3nm–2nm domestic capability around 2035, nearly a decade out.

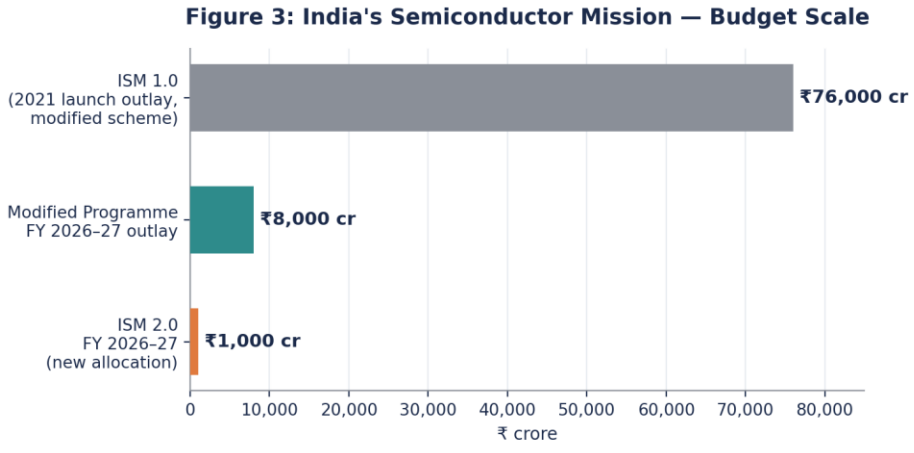


Figure 3: India's Semiconductor Mission budget scale

The budget numbers tell their own story: even the headline ISM 2.0 allocation is a fraction of the scheme's cumulative outlay since 2021, and a rounding error next to what TSMC or Samsung spend on a single advanced fab.

Data protection law is still being operationalized. The Digital Personal Data Protection Act was passed in 2023, but its implementing rules have only been rolling out in phases through 2025–26. Until those rules, covering consent mechanisms, data fiduciary obligations, and cross-border data transfer conditions are fully in force and tested, India's AI ecosystem is being built on a regulatory foundation that is still under construction. Companies are training models and deploying products against a moving compliance target, which is a real risk for any sector but particularly for one as data-hungry as AI.

Bias, language, and the limits of "Indian" AI. Most foundation models India's startups fine-tune are still built on English-dominant, Western training corpora. Claims of building "Indian" or "Bharat-first" AI are frequently more marketing than architecture, a vernacular interface bolted onto a foundation trained predominantly on data that under-represents Indian languages, dialects, and social context. Genuine multilingual capability across all twenty-two scheduled languages, with attention to caste, religious, and regional bias in training data, remains an unsolved problem, not a solved one.

The skilling and access gap. Cheap GPU-hours help registered startups and academic institutions. They do nothing directly for the roughly 800 million Indians without dependable broadband, or for a workforce where formal AI-adjacent skilling programmes still reach a small fraction of the graduates entering the job market each year. A "democratized" compute layer sitting on top of a deeply unequal access layer risks concentrating AI's gains in the same urban, English-speaking, already-credentialed cohort that has captured most of India's previous tech booms.

Digital Sovereignty: What It Would Actually Take

"Digital sovereignty" is invoked constantly in Indian policy discourse, but it is worth being precise about what it requires, because the term is currently doing more rhetorical than analytical work.

Genuine sovereignty in AI has at least four layers, and India is at a different stage in each:

1. **Data sovereignty**: control over where citizen data resides and how it can be used. India has made real progress here through data-localisation requirements and the DPDP framework, even if implementation is incomplete.
2. **Model sovereignty**: the ability to train and control foundation models domestically. India is at an early stage: Sarvam and a handful of others are building open-source models, but none yet approach frontier scale, and the underlying training largely depends on subsidised, foreign-designed compute.
3. **Compute sovereignty**: domestic capacity to manufacture the chips that power AI. This is the weakest layer. India's semiconductor mission is real but is, by its own government's framing, a decade-plus project, and even its near-term wins (28nm fabs) are generations behind frontier requirements.
4. **Governance sovereignty**: the regulatory and institutional capacity to set rules for AI on India's own terms rather than importing them wholesale from the EU's AI Act or US executive orders. India has been deliberately cautious here, favouring a "pro-innovation" light-touch approach over hard regulation, which is a defensible bet but also means India is, for now, a rule-taker more than a rule-maker in global AI governance conversations.

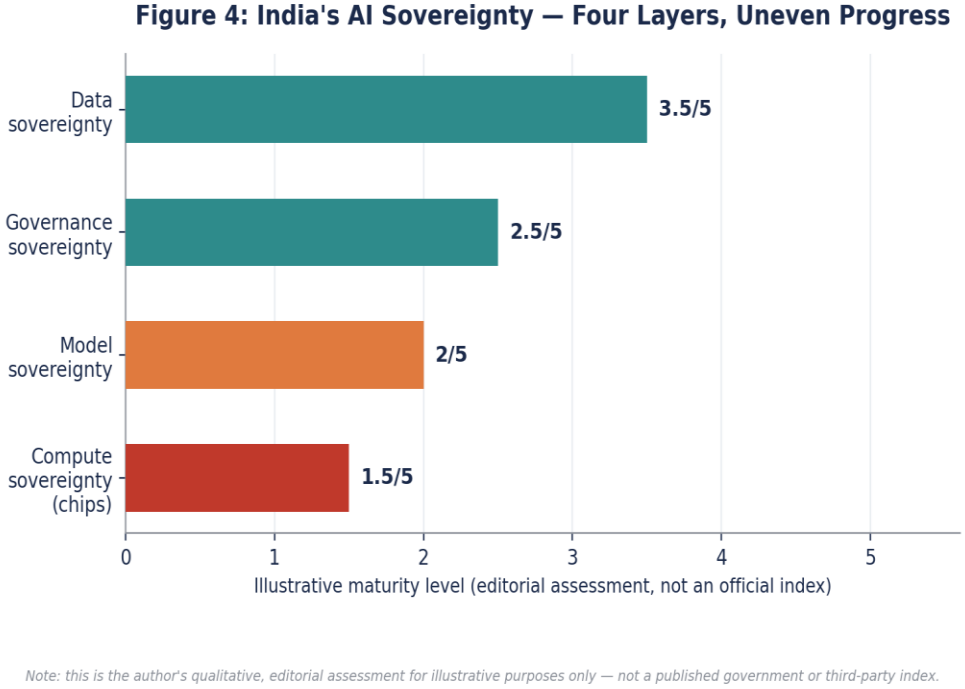


Figure 4: India's AI sovereignty across four layers — uneven progress

The honest assessment is that India has made the most progress on the layer that costs the least and yields the most headlines, deploying compute and subsidising access and the least progress on the layers that require decade-scale industrial capability: chips and frontier models. That is not a criticism of strategy so much as an acknowledgment of constraint. No country outside the US, China, and arguably Taiwan and a handful of European/Gulf actors with extraordinary capital is close to full-stack AI sovereignty. India's realistic goal is not autarky; it is reducing single points of dependency enough that a geopolitical shock, an export control, a trade dispute, a platform policy change cannot unilaterally switch off India's AI capability.

The Road Ahead

Three things would meaningfully move India from "AI adopter with sovereign ambitions" toward "AI power with genuine leverage":

First, sequencing compute and chips honestly. The GPU subsidy programme buys time, not independence. The real test of seriousness is whether ISM 2.0's upstream focus equipment, materials, design IP survives budget cycles long enough to produce results, because the payoff horizon is measured in years, not election cycles.

Second, treating vernacular and inclusive AI as infrastructure, not as a startup vertical. If India wants AI gains to reach beyond its existing tech-economy cohort, public investment in genuinely India-representative training data, multilingual benchmarks, and offline/low-bandwidth deployment models needs the same institutional seriousness currently reserved for compute clusters.

Third, finishing the regulatory foundation before, not after, AI deployment scales further. A data-protection regime whose rules are still being phased in while AI adoption accelerates is a recipe for either weak enforcement or retroactive disruption. Clarity now, even if imperfect, is more valuable than a "wait and see" posture that lets practice run ahead of law.

India's AI story is real, but it is not yet the story the headlines suggest. The country has genuine, scarce advantages population-scale digital infrastructure, deep engineering talent, and a government willing to spend on the visible parts of the AI stack. It has equally genuine and harder-to-close gaps in semiconductor depth, frontier model capability, completed data-governance law, and equitable access. "Digital sovereignty" will not arrive as a single policy announcement; it will be the cumulative result of a decade of unglamorous investment in the layers that don't generate summit headlines fabs, design IP, multilingual data, and finished regulation. Whether India closes that gap before the next geopolitical chip shock arrives is the question that will determine whether this decade is remembered as India's AI revolution, or merely its AI subscription.

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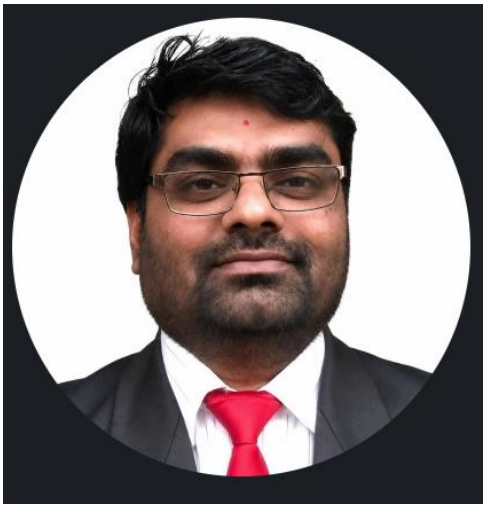
About the Author



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Semiconductor Self-Reliance and India's Digital Future:

IMPLICATIONS FOR COMMUNICATION TECHNOLOGIES AND IoT

VI.

Semiconductor Self-Reliance and India's Digital Future: Implications for Communication Technologies and IoT

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Few innovations in human history possess the profound, yet entirely obscured, influence of the semiconductor chip. They wake us up via the smartphone alarm. They confirm our digital payment in one tap. They monitor heartbeats in silence via the wrist. Hidden beneath all the ordinary sound is the tiny piece of silicon, no bigger than a thumbnail, performing the same amount of computing as was performed by several large machines fifty years ago. They operate in total anonymity, and that is exactly how they were engineered to work.

For most of its existence, the semiconductor industry had been happy to remain unnoticed, just a supply chain industry, but not a headline one. Things began to change around 2020 and have never reverted since.

The Shortage that Changed the Conversation

In early 2021, car manufacturers around the world started doing something nobody expected: idling assembly lines not because they lacked steel or workers, but because they couldn't get hold of chips worth a few dollars apiece. Toyota, Ford, and Maruti Suzuki all cut production. Global automakers lost an estimated $210 billion in revenue that year alone, according to industry estimates at the time, almost entirely because of a component most car buyers had never given a second thought to. Laptops got more expensive. Gaming consoles vanished from shelves. Even something as mundane as a washing machine controller became hard to source.

The chip shortage wasn't really about chips running out. It was about the world discovering, all at once, how few places actually make them. Taiwan alone fabricates over 60% of the world's semiconductors and more than 90% of the most advanced ones.

A handful of companies- TSMC, Samsung, and Intel sit at chokepoints that the rest of the global economy quietly depends on. When one link in that chain wobbled, everything downstream felt it within weeks.

For India, this wasn't an abstract lesson. It was a mirror. The country had spent two decades building one of the world's most impressive digital economies, UPI

processes more transactions today than most Western card networks combined, Aadhaar underpins a billion identities, and India's mobile data is among the cheapest on earth.

Despite the widespread digital presence, hardly any of the foundational silicon architecture is produced domestically. India's rapidly growing digital economy is built on largely imported hardware infrastructure.

This stark contrast where a nation leads in global software development and digital services yet relies heavily on foreign supply chains for physical hardware has prompted a significant policy shift. As a result, achieving semiconductor self-reliance has moved from a specialized bureaucratic discussion to become a crucial element of national strategic sovereignty.

From Announcement to Output

For years, India's semiconductor mission seemed to be stuck in a cycle of paperwork, grand announcements, and ambitious five-year plans that never materialized. Today, that pattern has broken. The shift from paperwork to production is happening with remarkable speed. Look at Sanand, Gujarat: in February 2026, Micron’s advanced packaging facility transitioned from a sprawling construction site into an active, operational production line. It's now producing actual memory chips for global supply chains, powering a range of devices from smartphones to electric vehicles.

This is the first truly operational milestone for the current mission. It's no longer just a proposal or political promise; it's real hardware coming off a domestic assembly line.

Since then, momentum has built fast. A packaging facility from Kaynes Semicon went commercial within fourteen months of breaking ground, with a daily output capacity north of six million components. Tata Electronics, in partnership with Taiwan's Powerchip Semiconductor Manufacturing Corporation, is racing toward "first silicon": the moment a fab actually produces working wafers at its Dholera site before the year is out.

In May, Tata signed an agreement with ASML, the Dutch company that makes the extraordinarily precise lithography machines without which no advanced chip factory can function; the Dholera fab itself is being built for roughly $11 billion and targets a capacity of 50,000 wafers a month.

By mid-year, thirteen projects were approved across seven states, with committed investment crossing ₹1.6 lakh crore, the largest single-year semiconductor budget allocation India has ever made.

Gujarat has become the clear centre of gravity, with Sanand and Dholera anchoring most of the activity. But Assam now hosts a Tata packaging facility in Morigaon, Odisha has broken ground on advanced 3D chip packaging, and Rajasthan opened its first semiconductor plant this year, notably, one built entirely outside the central mission's funding, on state initiative alone. This is no longer a story about one government scheme. It's starting to look like an actual industry taking root in more than one place at once.

None of this makes India a semiconductor manufacturing power on the scale of Taiwan or South Korea, and it would be dishonest to pretend otherwise. But four years ago, India had essentially no commercial chip-fabrication base at all. Today it has working factories, signed equipment deals, and a second phase of policy already underway. **That's the real headline even though it's a quieter one than the ministerial photo-ops suggest.**

Why is India chasing the "wrong" chips - on purpose?

Here's a detail that's easy to miss but tells us a lot about the strategy underneath all this activity: the Dholera fab isn't being built to chase the world's most advanced chips. It's targeting the 28-nanometre range and coarser, not the cutting-edge silicon inside a flagship phone or an AI data-centre accelerator, but the workhorse chips that run power management systems, automotive electronics, display drivers, and industrial sensors.

As the world fixates on the competition for 2-nanometer chips, India's strategic move toward mature nodes is a thoughtful and practical decision. The expansive IoT and 5G networks don't require the latest processors for applications like water sensors or power meters; instead, they depend on large quantities of foundational, dependable silicon. Presently, nearly all of these essential chips are imported. India's real goal isn't to develop the tiniest transistors but to secure complete control over the hardware supply chain it relies on daily.

Communication networks are built one chip at a time

The evolution of networks hinges on specific hardware upgrades in areas such as radio-frequency (RF) chips, memory, and digital signal processors, rather than solely relying on abstract innovation.

The Reality of 5G: The core breakthrough of 5G technology is its ultra-low latency, crucial for applications like real-time remote surgery or industrial automation. Achieving this requires specialized hardware, including cell phone RF modules, high-capacity base station processors, and power-efficient network accelerators. If a base station's silicon is unable to process data rapidly enough, it becomes a hardware bottleneck that no software update can resolve.

The Stakes of 6G: Emerging 6G architectures aim to integrate communication with real-time AI and edge computing. This development demands a new generation of ultra-efficient AI accelerators. Nations capable of designing and manufacturing these specialized chips will have the power to dictate global communication standards, while those that cannot will have to adopt standards set by others.

Invisible Infrastructure: The reliance on hardware extends throughout our entire digital framework. Terrestrial optical fiber networks depend on specialized semiconductor lasers and optical detectors. Likewise, Low-Earth-Orbit (LEO) satellite constellations, essential for providing broadband access across India's remote areas, rely on rugged silicon engineered to withstand extreme conditions like temperature variations, radiation, and vibrations.

What does this mean for the Internet of Things?

The Internet of Things (IoT) introduces semiconductor self-reliance into everyday life, driven by large-scale production rather than cutting-edge technology.

The Hardware Reality: A single connected farm utilizes numerous soil sensors, a smart city depends on thousands of signal processors, and modern cars contain over a thousand individual chips for functions like braking, airbags, and dashboards. These applications don't require advanced silicon; they operate on cost-effective, mature-node chips that India's new manufacturing facilities are built to produce.

The Macro Impact: Localizing mature-node production fundamentally rewrites the economics of domestic technology. When a farmer's sensor kit, a hospital's patient monitor, or an industrial automation system is decoupled from volatile foreign exchange rates and prolonged shipping delays, innovation becomes affordable.

Strategic Takeaway: India doesn't need to surpass global leaders in innovation to dominate the IoT sector. It only needs to manufacture basic, reliable silicon within its borders, allowing its tech ecosystem to stop viewing imported hardware as a constant financial burden

The Part Nobody Puts on a Banner

An honest assessment indicates that India has succeeded in setting up factories, yet it lacks the intricate ecosystem needed to keep them operational.

The Supply Chain Blind Spot: A semiconductor manufacturing plant's independence relies on its inputs. Currently, India heavily relies on imports for nearly all essential components like specialized gases, high-purity chemicals, electronic design automation (EDA) software, and sophisticated lithography tools.

The Knowledge Gap: While it's possible to purchase equipment and offer incentives, acquiring decades of process expertise and establishing a localized supplier network is not. Achieving efficient production yields at scale demands an experienced talent pool that takes generations to develop.

The Policy Shift: In response, the government has realigned its approach with "Mission 2.0," redirecting funds from mere infrastructure development to the crucial aspects of equipment, materials, design intellectual property, and a comprehensive supply chain.

The Bottom Line: Countries like Taiwan and South Korea achieved their dominance in silicon manufacturing over many decades, rather than within a few policy cycles. India has made strides in entering active manufacturing sectors, but reaching true depth will require a long-term effort. Any declaration of immediate success is misleading.

Why is the world in a hurry to help?

India's sudden surge in hardware development is fuelled by a global shift rather than an absence of competition.

The Catalyst: This shift was spurred when Western export controls severely impacted major foreign telecom companies, highlighting how quickly hardware dependencies can be exploited.

The Opportunity: With growing tensions surrounding Taiwan and the race driven by AI for memory chips, the world is compelled to diversify its supply chains. India stands to gain significantly due to its vast domestic market, reputable engineering hubs in Bengaluru and Hyderabad, and strong diplomatic relations with the US, Japan, and Taiwan.

The Reality: Significant collaborations, such as Taiwan's top chipmakers sharing decades of expertise with India's first large-scale fabrication plants, reflect substantial confidence. Nonetheless, being seen as a secure option for global diversification does not equate to having developed self-sufficient capabilities. Both aspects are prevalent today.

India's Real Advantage and Its Real Test

The one bright spot that India certainly has going for it is talent that already exists instead of talent that has to be created. There are thousands of Indian engineers who design, validate, and test chips for the largest chip manufacturers in the world; the design center in Bengaluru has finished the layout of a 2-nanometre chip, which is considered to be one of the most advanced circuit designs in the world even though the chip itself would still be manufactured in TSMC in Taiwan.

Existing design skills are the real basis for building up manufacturing, packaging, and test capabilities around. India is far from square one; its massive global design footprint means thousands of domestic engineers already understand how these complex architectures operate.

Yet, a self-sustaining industry requires more than design acumen. It requires universities supplying special graduates on a big scale, research organizations coming up with innovative materials rather than purchasing those from elsewhere, start-ups ready to try chip design instead of more conservative software solutions, and finally manufacturers to bring it all into a functioning product. The Indian approach is quite logical since they aim not at complete self-reliance; no organization in this industry, including the US, tries to accomplish anything independently any longer. They want to be able to create sufficient domestic capacity so as to become not only the buyer but also an active participant in the international market chain.

The Question worth Sitting With

Every country that has tried to build a domestic chip industry has learned the same lesson eventually: **"Money is the easy part. What separates a fabrication line from a genuine ecosystem is everything that happens in the years after the factory opens"** whether local suppliers get good enough to be trusted with critical components, whether the engineers trained in these new facilities stay rather than take the next flight to a fab in Arizona or Hsinchu, whether the technology transfer that comes bundled with a foreign partnership actually gets absorbed and built upon rather than just borrowed.

India has, unmistakably, moved past the point of wondering whether it can attract semiconductor investment. **The fabs exist**. The first ones are already running. The question this decade will actually answer is quieter, and considerably harder to fake: will India end up owning the chips that run its own communication networks and connected devices or will it simply become a more efficient host for someone else's technology, a newer stop on a supply chain still designed and controlled elsewhere?

The honest answer, right now, is that nobody knows yet. But for the first time in India's semiconductor story, that's a genuinely open question rather than a foregone one and that, on its own, is worth paying attention to.

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