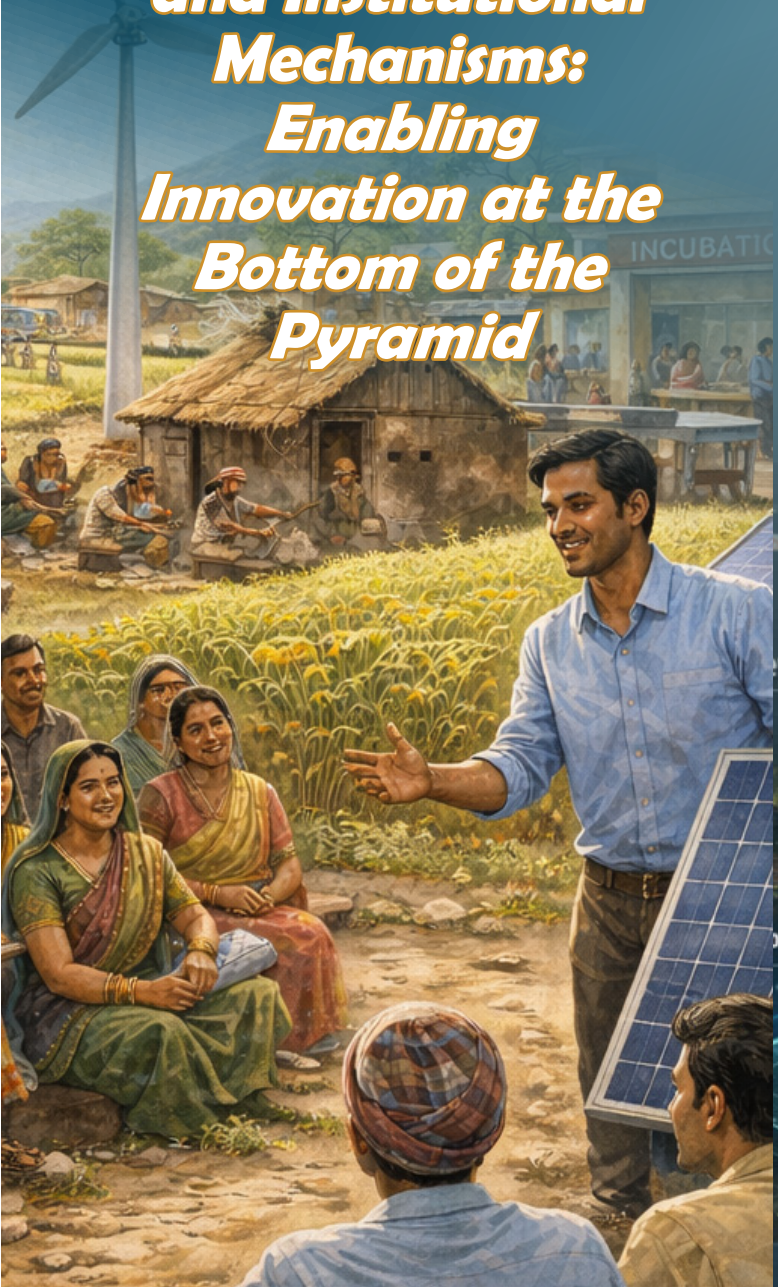
राष्ट्रीय नवप्रवर्तन प्रतिष्ठान – भारत
विज्ञान एवं प्रौद्योगिकी विभाग, भारत सरकार का स्वायत्तशासी संस्थान
National Innovation Foundation - India
Autonomous Institute of the Department of Science & Technology, Govt. of India

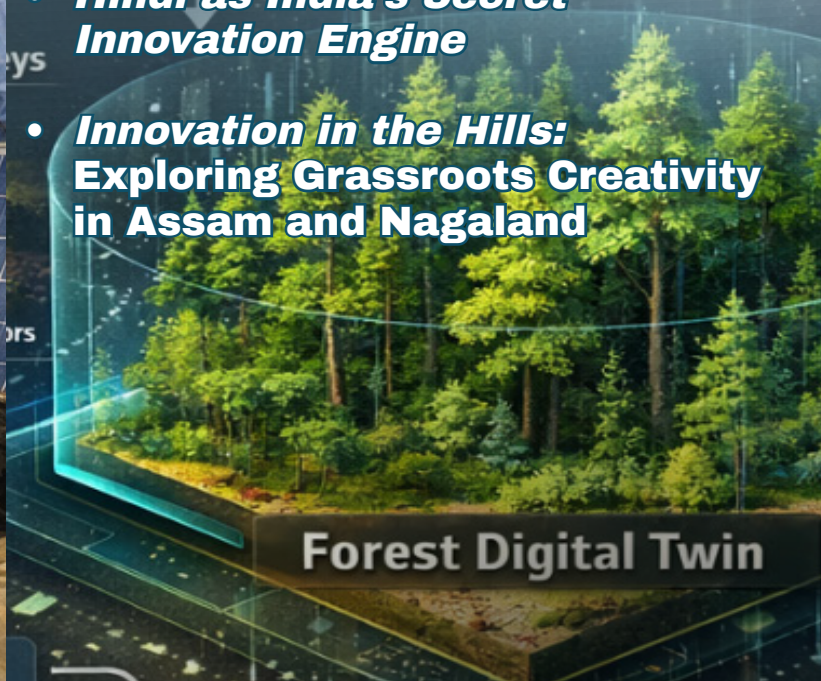
Innovation Frontline

May-June 2026 / Vol. 01 / No. 02

Policy Support and Institutional Mechanisms: Enabling Innovation at the Bottom of the Pyramid



- Inclusive development through in situ incubation of grassroots Innovations
- Women innovators in Technology: Catalysts of Change
- Building a Forest Digital Twin for India
- Tick control measures and significance of ethnobotanicals for livestock health system
- *Hindi as India's Secret Innovation Engine*
- *Innovation in the Hills:* Exploring Grassroots Creativity in Assam and Nagaland



Editor-in-Chief
Dr. Arvind C. Ranade

Editor
Dr. Rintu Nath

Publication Committee:
Dr. Vivek Kumar
Dr. R K Ravikumar
Dr. Nitin Maurya
Er. Rakesh Maheshwari
Shri Hardev Choudhary
Dr. Satya Singh

Design
Ms. Bhavya Singh

Address for correspondence
National Innovation Foundation - India
Grambharti, Amrapur, Gandhinagar,
Gujarat- 382650

Tel: +91-02764-261131, 32

e-mail
info.nif@nifindia.org

website
https://www nif.org.in

Published by Dr. Arvind C. Ranade on behalf of National Innovation Foundation -India

Contents

Editorial

Creative industries, including traditional as well as modern arts, crafts, design, entertainment, architecture, literature, etc. have been a pivotal force in accelerating human advancement. These domains present massive opportunities for people to stimulate solutions that can propel inclusive and sustainable development. The United Nations General Assembly's designation of 21 April as World Creativity and Innovation Day, recognizes, what Indian civilisation has long demonstrated, that the act of creation is inseparable from the act of living. The Rigvedic invocation navo navo bhavati jāyamānaḥ, "he becomes ever-new even as he is born", framed renewal as the natural condition of being. Aryabhata's articulation of the decimal place-value system in the fifth century, Bhaskara II's iterative algorithms, and the syncretic textile, metallurgical, and water-harvesting traditions of pre-modern India each reflect a civilisational disposition in which creativity was neither an elite occupation nor a residual activity, but a continuous practice deeply embedded in agriculture, craft, governance, and daily life.

The statistical record of India's contemporary innovation underscores this continuity. India ranks 38th in the Global Innovation Index 2025, a sustained rise from 81st in 2015, and is today the world's third-largest innovation ecosystem with nearly 2 lakh recognised startups across the country. Patent grants in India have risen sharply over the past three years, signalling a maturing intellectual property culture. Beyond aggregate figures, there is a continuous expansion at the grassroots in form of ideas, innovations, and traditional knowledge practices documented across over 700 districts, sustained by our farmers, artisans, students, rural women, etc. whose ingenuity defines the nation's creative depth.

This dual paradigm of formal and frugal is now the operative architecture of Indian innovation ecosystem. The Atal Innovation Mission's network of more than 10,000 Atal Tinkering Labs, the INSPIRE-MANAK scheme that mobilises lakhs of school students annually, the Anusandhan National Research Foundation, and the recently approved Research, Development and Innovation (RDI) Scheme with its fund-of-funds design, create a continuum from school-level ideation to commercial diffusion. However, structural gaps persist in technical validation, manufacturing standardisation, intellectual property protection, and market access, and intermediating institutions remain central to addressing them.

NIF's twenty-five-year institutional record is a measured response to precisely these gaps. Through intensive scouting and documentation, R&D validation, intellectual property filing, in-house incubation, Diffusion, and the iPhD programme, NIF translates dispersed grassroots creativity into protected, validated, and commercialisable enterprise. The conferment of Padma Shri honours upon the nearly a dozen grassroots innovators illustrate how experiential creativity, when met with institutional support, produces both economic value and social dignity. The complementarity between bottom-up ingenuity and top-down architecture is what converts isolated brilliance into systemic capability.

As India advances towards Viksit Bharat 2047, the occasion of World Creativity and Innovation Day offers an occasion for renewed commitment. Creativity and innovation, in the Indian understanding, are neither imported categories nor sectoral activities but they are civilisational habits that must be instilled in every generation through institutions, incentives, and recognition. The Honorable Prime Minister's call of Jai Anusandhan, added to the older trinity of Jai Jawan, Jai Kisan, Jai Vigyan, locates research and creative practice at the heart of the comprehensive national development project. ■

Dr. Arvind C. Ranade

Policy Support and Institutional Mechanisms: Enabling Innovation at the Bottom of the Pyramid

Govinda Bhattacharjee

Introduction

In his book "The Fortune at the Bottom of the Pyramid", C. K. Prahalad, who pioneered the concept of Bottom of Pyramid (BOP) in India wrote, "If we stop thinking of the poor as victims or as a burden and start recognizing them as resilient and creative entrepreneurs... a whole new world of opportunity will open up." This is what is referred to as inclusive capitalism. It has revolutionised corporate marketing strategies through innovations, like the introduction of small sachets of shampoo and detergents by Hindustan Unilever in what is known as the Sachet Revolution, or in Aravind Eye Care System of providing low-cost high-quality eye surgeries through a cross-subsidy model, whereby wealthy patients pay for the poor. A quiet revolution is now taking place again, not in the formal R&D labs of elite engineering ecosystems, but at the grassroots level through decentralized, frugal, and context-specific solutions. Like marketing, it also has the power to revolutionise our economic growth with appropriate policy support.

Frugal and grassroot innovation is a speciality and strength of India, where resource scarcity has catalysed novel solutions through frugal innovation - solutions that are affordable, adaptable, sustainable and relevant. But then there are several challenges related to scaling and market integration. The commercial success of these grassroots innovations is often hindered by insufficient market access, weak branding, and the absence of distribution networks. Grassroots innovators from informal economies, facing limited access to institutional funding, usually don't know how to manage intricate IPR frameworks to patent their inventions or interact with formal bodies. National science and technology policy considers inclusive innovation to be essential, and while mechanisms like the NIF, Atal Innovation Mission, and Startup India are in place to help incorporate it, its capabilities are not being fully leveraged.

AI generated

Of course, there are many success stories, like the Honey Bee Network (HBN) that was founded in the 1980s, to promote ethical knowledge sharing, recognition, and reciprocity. It has so far documented over 170,000 innovations from across the country, creating a vast repository of grassroots knowledge, helping the cross-pollination of ideas across communities while protecting the IPR of innovators. Supported by SRISTI (Society for Research and Initiatives for Sustainable Technologies and Institutions) to provide research and documentation support, GIAN (Grassroots Innovation Augmentation Network) for incubation and enterprise support and NIF for scaling patenting, and commercialization, the Network provides an integrated, decentralised and participatory model for shifting from isolated innovation support to ecosystem-building. This ecosystem provides the three V's necessary for technological growth: Validation

of claims through scientific testing, Value addition by improving the aesthetics and ergonomics of the prototype products, and Venture capital through seed funding to transform a backyard workshop into a small-scale factory. The success of this investment is measured by its social impact – specifically, how many lives are improved for every rupee spent – rather than just its financial gains. This invention harnesses traditional pottery techniques to craft a clay refrigerator that functions without electricity, relying on the fundamental science of evaporative cooling. Designed with rural and low-income households in mind, this clay fridge offers an affordable and eco-friendly cooling solution. The Honey Bee Network identified this product, GIAN provided incubation and business development support, while NIF facilitated design refinement, patenting, and commercialization. Recognised nationally and internationally, Mitticool conclusively demonstrates the power of grassroots innovation, and stands out as a shining example of how institutional mechanisms can transform localized knowledge into globally relevant technology, of transforming informal innovation to formal enterprise mediated by supportive policy and enabling institutional frameworks. This zero-energy, zero emission cooling system is now a standardized assembly-line product exported to over 50 countries, including many poor countries in Africa. It shows how a sophisticated understanding of thermodynamics can be applied to traditional craftsmanship in a way that is not only just "cheap", but environmentally sustainable and culturally resonant.

India's technological future will depend on the ability to move from isolated success stories to systemic transformation

Mitticool consists of a dual-chambered clay body where water stored in an upper water tank slowly drips down the porous sides. As this water evaporates, it absorbs latent heat from the inner storage chamber, reducing internal temperatures by as much as 8 degrees compared to the ambient temperature. Research indicates that it can prolong the freshness of vegetables by two to three days and milk by one day, all without needing external power. At Rs 6,000, its price is significantly lower than the Rs 20,000 charged for a compressor-based refrigerator.Another landmark and transformational example of frugal engineering is the Jaipur Foot, developed in 1968 by Dr. P.K. Sethi and Ram Chandra Sharma, designed specifically for Indian population. While Western prosthetics such as the SACH foot are intended for shoe-wearers, the Jaipur Foot is specifically crafted for floor-sitting. This prosthetic, unlike costly Western models, allows for actions such as squatting, sitting with legs crossed, navigating rough country paths, and even ascending trees. Made from high-density polyethylene (HDPE), vulcanized rubber, and wood, its distinct internal "universal joint" of sponge rubber layers enables dorsiflexion, inversion, and eversion. Its cost? Only Rs 3000, compared to 20,000 for a SACH foot. Bhagwan Mahaveer Viklang Sahayata Samiti (BMVSS), a non-governmental organization, has supplied these prosthetics without charge to more than 1.6 million individuals worldwide, establishing itself as the premier global provider of artificial limbs. This technology has been implemented in more than 50 nations, especially in conflict-ridden areas such as Afghanistan and Rwanda, where individuals who have lost limbs to landmines need durable, easy-to-maintain mobility devices.A critical addition to the HBN-NIF ecosystem is BIRAC (Biotechnology Industry Research Assistance Council) in 2012. By providing Biotechnology Ignition Grants (BIG), BIRAC has allowed rural innovators to access high-end labs to refine their products. This created a "Lab-to-Land-to-Lab" loop: an idea born on a farm (Land) is refined in a city (Lab) and sent back for mass deployment (Land). Through its flagship programme BioNEST, BIRAC has created 20 world-class bio-incubators with 2 lakh Sq. ft of incubation space, providing support from office space to access to top-end instrumentation and mentor networks. These successes are not accidental; they are the outcomes of a rigorous "scouting and documentation" process that includes biennial Shodh Yatras organised by the HBN which are 100–200 km journeys of exploration on foot through remote villages to identify innovators who have developed local solutions but lack the means to scale them. The NIF has now built a database of over 345,000 technological ideas and has filed more than 1,400

patent applications on behalf of unlettered grassroots innovators to ensure their intellectual labour is protected from corporate exploitation. Globalisation of these products means that India is not only innovating to address its problems, but also creating a blueprint for the 4 billion people globally who live in resource-constrained environments. This is what is expected of a country that aspires to be a champion of the global south. There are other wonderful examples of frugal engineering as well, storis that attracted global admiration and envy. Take the Mangalyaan (Mars Orbiter Mission) that cost only $74 million, less than the budget of the Hollywood film Gravity. Instead of designing from the scratch, it used existing satellite bus technologies to design, combined with ground-based simulations to reduce the number of expensive physical prototypes and finally optimised the trajectory by using Earth's gravity to propel the craft, saving massive amounts of fuel. This innovation mindset has turned India into a global hub for low-cost satellite launches, extending the BOP even to space. Perhaps the most significant "grassroots" revolution has been the India Stack, especially the Unified Payments Interface (UPI). While it was developed by the government agency (NPCI), its success lay in its "grassroots adoption." By creating an open and secure protocol system, India allowed even the smallest, almost illiterate, street vendor to participate in a high-tech digital economy. This "top-down infrastructure for bottom-up innovation" is a unique Indian model that the world is now watching and adopting, confirming India's credibility as the leader of global south.I personally came across another simple but useful BOP-innovation - a simple, inexpensive, environment friendly and safe water-purifier called Amritadhara to provide safe drinking water, free from chemicals, especially Arsenic, and bacterial contamination, drawing upon common practices. Developed by an NGO based in West Bengal called PRISM, it uses the Oxico-Flock Sedimentation Technique designed to remove suspended solids, colloids, and pathogens, which operates by clumping fine particles into larger, heavier aggregates known as flocs, which then settle to the bottom by gravity. Technical guidance for this device was provided by the All-India Institute of Hygiene and Public Health, Kolkata, and the cost of units supplied free to rural families in North Bengal was borne by private donors. It is again a step towards Atmanirvarta, or self-sufficiency, using local resources and local technology to solve local problems. It has received no government support so far. Grassroots innovation is no longer a peripheral activity; it is the cornerstone of India's "Atmanirbhar Bharat" (Self-Reliant India) vision. To fully realize the potential many grassroots innovations like the ones discussed above, we need an ecosystem for strengthening incubation and scaling up, establish and strengthen coordination among institutions, give access to finance and credit, simplify the intellectual property processes and integrate the grassroots innovation into formal education and R&D systems. India's technological future will depend on the ability to move from isolated success stories to systemic transformation, and this will need substantial policy support to move from an elite-driven top-down model to a distributed, participatory, and inclusive process rooted in the lived experiences of ordinary people. ■

References

- Prahalad, C. K. (2004). The fortune at the bottom of the pyramid: Eradicating poverty through profits. Wharton School Publishing. (pp. 1–3, 25–30)
- Hindustan Unilever Limited. (2015). Creating shared value report.
- Rangan, V. K., & Thulasiraj, R. D. (2007). Making sight affordable (Innovations Case Narrative: Aravind Eye Care System). Harvard Business School. (pp. 3–8)
- National Innovation Foundation. (2022). Annual report.
- Gupta, A. K. (2016). Grassroots innovation: Minds on the margin are not marginal minds. Penguin. (pp. 45–80, 120-125)
- National Innovation Foundation. (2015). Case study: Mitticool refrigerator. (pp. 2–6)
- BMVSS. (2019). Annual report. (pp. 5–12)
- Sethi, P. K. (1972). The Jaipur foot. The Journal of Bone and Joint Surgery, 54(4), 800–803.
- Department of Biotechnology. (2020). National biotechnology development strategy.

Dr. Govinda Bhattacharjee is a retired bureaucrat presently engaged in teaching public policy and public finance at the Arun Jaitley National Institute of Financial Management. He is a well-known popular science writer and has authored a trilogy on evolution. He writes regularly in various newspapers and academic journals on diverse issues.

Email: govind100@hotmail.com

Inclusive development through in situ incubation of grassroots Innovations

Ankita Singla and Vipin Kumar

Introduction

The grassroots and community-based innovations are increasingly turned attention toward the search for sustainable, inclusive and livelihood oriented development pathways. Individuals and informal sector players continuously generate context-specific solutions to local issues in agriculture, health, animal husbandry, livelihoods etc. In spite the value and potential, a continuous gap remains between ideation and large scale application. Bridging this gap, requires not only institutional support but also a rethinking of where and how grassroots or social innovations are nurtured. In this context, the concept of in situ incubation of supporting innovators at their place of origin has emerged as a powerful model for accelerating the transformation of ideas into viable products, enterprises and local solutions.The rationale for in situ incubation lies in the recognition that the innovation is deeply embedded in local socio economic, ecological and cultural contexts. Conventional centralised incubation systems generally ignore these contextual dimensions, leading to mismatches between technologies and end user needs. However, in situ incubation emphasises on user driven design refinement and decentralised productions. This approach not only reduces the time to market but also reduce supply chain and other associated costs. Also, the decentralised manufacturing considerably contribute to resilience limiting dependence on conventional logistics networks, which is a major concern for global disruptions. A large number of technologies developed by individuals across the country can be made available to regional and national markets through medium, small and micro enterprises, particularly when they are incubated at their location of origin. The purpose, thus, is to improve productivity, reduce costs, enhance sustainability, trigger creativity and essentially reduce the time to market of technologies which, if not addressed may saturate the pipeline of innovations. Some technologies that have proven successful at their respective locations need to be replicated by creating awareness among farmers and other end users in different states. There is, therefore, an urgent need to demonstrate their potential across regions to enable a distributed entrepreneurial upsurge for inclusive development (Pansera and Owen, 2018).It is also necessary to enhance the rate of new product development based on local knowledge to reduce drudgery and improve the efficiency of the common man. In the current innovation-driven era, this requires a substantial increase in the resource base so that more impactful results can be achieved. One way to accomplish this is to add value at the local level through a network of reputed national public and private laboratories, design and fabrication firms and companies. Investments need to be made for value addition, market research, redesigning products for local adaptation, intellectual property protection and achieving commercial objectives for ensuring financial sustainability and end user satisfaction. It is important to emphasise that commercial application alone is not the sole objective. The development of open source technologies, which can be disseminated through local networks under an open innovation framework can generate livelihood opportunities, reduce costs, and improve other outcomes.

It is also necessary to enhance the rate of new product development based on local knowledge

No single institution or individual can address such challenges, a collaborative culture must be fostered so that the problems of small enterprises, the informal sector and local communities in disadvantaged regions can be solved in a time-bound manner. The community-driven participation and empowering local ecosystems are essential to transform grassroots innovations into impactful, sustainable

development outcomes (Sapienza and B. Maarouf, 2025). Innovations should be selected based on criteria such as socio-economic impact, originality, environmental and gender implications and local maintainability or replicability. It is well recognized that innovators do not always become successful entrepreneurs, making it essential to link innovators with entrepreneurs and investors.

Support to innovators at early stages for proof of concept development, prototyping, testing in addition to market research and social need assessment is necessary. The product development requires efforts with a focus on affordability considering knowledge gap analysis, technical benchmarking and user feedback as essential prerequisites.This need strong coordination in public and private sectors, research and development institutions, industry associations, clusters and innovation intermediaries.

Ensuring traceability to standard systems of units requires precision calibration, which can be achieved through technologically controlled laboratory processes. Product fine-tuning is an indispensable part of the development cycle. For achieving the competitive pricing, the grassroots innovators need rigorous refinement processes. Since quality is defined as "conformance to requirements," it is must to be with proper mentoring, so the final product can compete in the market. The ultimate goal is to position the innovation in the mind of the end user with minimal effort and maximum appeal. The awareness building activities always necessary for scaling and outreach cannot be achieved without effective dissemination strategies.

In general, innovators from the grassroots often face constraints in achieving the scale of production or market their innovations and many innovations remain confined to the prototype stage. Therefore, there is a clear need for dedicated institutions to support innovators and entrepreneurs directly or through Technology Business Incubators (TBIs), which may also take equity stakes in such ventures on achieving the sustainability. In the recent policy discussions and global development, there is an emphasis on supporting decentralised, demand driven and inclusive innovation models. The World Bank (2023) reported the significance of local innovations in inclusive societal growth, while the GEM (2023) and UNDP (2024) highlights the significance of community led innovation in achieving sustainable development goals (SDGs). The necessity and strengthening of local and distributed innovation ecosystems was revealed OECD (2024, 2025). NITI Aayog (2021) has advocated strengthening grassroots innovation and local entrepreneurship through supportive policy frameworks and the efforts by the National Innovation Foundation-India (NIF) further demonstrate the impact of structured incubation including value addition and product development support to grassroots innovators. In conclusion, the in situ incubation of innovations is the need of hour and bridge the gap between creativity and market, which enable inclusive entrepreneurship and sustainable development. The support to local ecosystems, encouraging collaborations and providing targeted support will surely unlock the untapped potential of grassroots innovations and contribute significantly to nation. ■

References:
1.Pansera, M., and Owen, R. (2018). Framing inclusive innovation within the discourse of development: Insights from case studies in India. Research Policy, 47(1), 23-34.
2.NITI Aayog (2021). India Innovation Index 2021. NITI Aayog, New Delhi.
3.World Bank (2023). Expanding Opportunities: Toward Inclusive Growth (South Asia Economic Focus). World Bank, Washington, DC.
4.GEM (2023). Global Entrepreneurship Monitor 2023/2024 Global Report: 25 Years and Growing. GEM, London
5.United Nations Development Programme (UNDP) (2024). Human Development Report 2023–24: Breaking the Gridlock – Reimagining Cooperation in a Polarized World. UNDP, New York.
6.OECD (2024). OECD Digital Economy Outlook 2024 (Volume 1): Embracing the Technology Frontier. Organisation for Economic Co-operation and Development (OECD) Publishing, Paris.
7.OECD (2025). OECD Science, Technology and Innovation Outlook 2025: Driving Change in a Shifting Landscape. OECD Publishing, Paris,
8.Cottica, E. Sapienza and B. Maarouf (2025). At the edge of participation. How Research and Development is promoting civic engagement and enabling collective intelligence in the Global Majority. United Nations Development Programme, UNDP, New York. .

Ms. Ankita Singla is Junior Fellow at National Innovation Foundation – India (NIF). She holds a M.Tech in Agricultural Systems and Management and at present associated with Business Development division.
Email: ankitas@nifindia.org

Dr. Vipin Kumar is Chief Scientist and Former Director at the National Innovation Foundation – India (NIF). His research and interest areas are incubation and promotion of innovations by value addition, intellectual property protection, and commercialization. He leads the Business Development team.
Email: vipin@nifindia.org

Women Innovators in Technology: Catalysts of Change

Kinkini Dasgupta Misra

Introduction

There is a quiet but powerful shift underway in the world of innovation. It is not always visible in headlines dominated by billion dollar startups or cutting-edge laboratories, but it is unfolding steadily across research institutions, small enterprises, and rural communities. In India, women innovators are playing a central role in this shift, reshaping technology in ways that are not only advancing science but also making it more inclusive, empathetic, and grounded in real life needs. Their journeys reveal that innovation is not merely about invention; it is about understanding lived realities and designing solutions that are meaningful and accessible.

This transformation goes beyond participation. Women are not simply entering innovation ecosystems, they are redefining them. They are expanding the very idea of innovation what it looks like, where it originates, and who it serves. Whether in high-technology sectors or in grassroots communities, women are acting as catalysts of change, ensuring that innovation is not just technologically advanced but socially relevant.

The Evolving Innovation Landscape in India

India's innovation ecosystem has witnessed rapid growth over the past decade, driven by policy initiatives, increased digital adoption, and a thriving startup culture. Within this evolving landscape, women are emerging as a significant force. According to NITI Aayog, there has been a steady rise in women entrepreneurs across sectors, including in Tier-2 and Tier-3 cities. This shift indicates that innovation is no longer confined to metropolitan hubs but is becoming more geographically dispersed.

At the same time, structural gaps persist. Women-led startups receive a disproportionately small share of venture capital, often estimated at less than 10% highlighting persistent inequalities in access to funding. While India has one of the highest proportions of women STEM graduates globally, their participation in the workforce drops significantly over time. This "leaky pipeline" reflects challenges such as limited mentorship opportunities, workplace biases, and the disproportionate burden of caregiving responsibilities.

From an economic perspective, the stakes are high. Insights aligned with the World Bank suggest that increasing women's participation in the workforce could significantly boost India's GDP and overall productivity. Yet, unlocking this potential requires addressing systemic barriers and creating an environment where women can not only participate but also lead.

The inclusion of women in innovation is not just a matter of representation, it is a matter of relevance. Innovation is shaped by perspective, and when women are part of the process, solutions tend to be more inclusive and contextually grounded. Women innovators often draw from lived experiences, addressing issues related to healthcare, water, energy, and livelihoods. This diversity of perspective strengthens innovation systems,

AI generated

making them more adaptable and impactful.

Women in Deep Technology

The foundation of modern innovation lies in STEM (science, technology, engineering, and mathematics). Women's participation in these fields is therefore critical to building a strong and future ready innovation ecosystem. India has made notable progress in this regard, with women constituting a significant share of STEM graduates. However, the transition from education to sustained careers and leadership roles remains uneven.

Pioneering figures such as Kiran Mazumdar Shaw have demonstrated that science-led enterprises can achieve both global competitiveness and social impact. Building on this foundation, a new generation of women innovators is shaping emerging technologies. Leaders like Geetha Manjunath, Ashwini Asokan, Prukalpa Sankar, and Upasana Taku are influencing fields such as artificial intelligence, healthcare technology, and fintech.

Their contributions highlight an important dimension of innovation, the growing emphasis on user-centric and inclusive design. In areas like artificial intelligence, where biases in data and algorithms can have far reaching consequences, diverse perspectives are essential. Women innovators are helping ensure that technological systems are not only efficient but also ethical and equitable.

Despite these advancements, challenges remain particularly pronounced in deep-tech sectors, which often require long term research, sustained funding, and strong institutional support. Women in these fields frequently encounter barriers such as limited access to capital, fewer leadership opportunities, and interruptions in career progression. Addressing these challenges requires systemic interventions that go beyond increasing participation to enabling sustained leadership.

In response, several policy and institutional initiatives have been introduced in India. Programmes led by NITI Aayog, along with schemes such as WISE, KIRAN, and Vigyan Jyoti from the Department of Science and Technology, aim to support women across the innovation lifecycle. Complementary initiatives like Startup India and Stand-Up India focus on improving access to funding and entrepreneurial support. Together, these efforts are gradually shifting the focus from inclusion to empowerment.

Grassroots Innovation and Women's Leadership

While much attention is often given to high-technology innovation, an equally important and often under recognized domain is grassroots innovation. In rural and semi-urban India, women are at the forefront of solving everyday challenges through locally grounded and resource efficient solutions.

These innovations are deeply embedded in lived realities. Women are developing fuel-efficient stoves to reduce health risks, creating low-cost sanitary products to improve hygiene, designing water conservation systems, and experimenting with sustainable agricultural practices. Such innovations are not only practical but also socially transformative, addressing issues that directly impact community well-being.

Organizations like the National Innovation Foundation have documented thousands of grassroots innovations across the country. A significant number of these are driven by women or directly benefit them. Despite limited access to formal education or institutional support, these innovators demonstrate remarkable creativity and resilience.

However, grassroots women innovators often remain invisible in mainstream innovation narratives. Their work is rarely scaled, patented, or commercialized due to lack of awareness, funding, and institutional support. This invisibility limits the broader impact of their innovations and underscores the need for more inclusive recognition systems.

The status of grassroots women innovators in India reflects both promise and constraint. On one hand, millions of women are actively engaged in community-based innovation and entrepreneurship. Over 80 million women are part of self-help group networks under national livelihood missions, creating a strong foundation for collective innovation and enterprise.

On the other hand, only a small fraction of grassroots innovations transition into formal markets or receive intellectual property protection. This gap highlights systemic challenges that continue to hinder progress. Limited digital literacy, restricted access to financial resources, lack of exposure to markets, and social norms that constrain mobility all play a role in limiting opportunities. Moreover, innovation ecosystems often remain urban-centric, making it

difficult for grassroots innovators to access incubation, mentorship, and funding opportunities. As a result, many promising ideas remain localized, benefiting only small communities rather than reaching wider populations.

Addressing these challenges requires a shift in perspective from viewing grassroots innovation as peripheral to recognizing it as central to inclusive development. Women innovators at the grassroots level possess deep contextual knowledge, enabling them to design solutions that are both practical and sustainable.

Bringing Technology to the Grassroots

Technology has the potential to play a transformative role in enabling grassroots women innovators, provided it is accessible, affordable, and contextually relevant. Digital inclusion is a critical starting point. Access to smartphones, internet connectivity, and digital literacy can open new pathways for learning, collaboration, and entrepreneurship.

Digital platforms can significantly enhance market access. By connecting women directly to consumers, e-commerce and online marketplaces reduce dependence on intermediaries and increase income opportunities. Similarly, fintech solutions such as digital payments, microloans, and crowdfunding can help overcome traditional financial barriers.

Technology also enables knowledge sharing and skill development. Online training platforms can provide women with access to technical skills, entrepreneurial training, and information on intellectual property rights. This not only strengthens their capacity to innovate but also enhances their ability to scale and sustain their innovations.

The role of technology is equally important in visibility and recognition. Digital storytelling, documentation platforms, and social media can bring grassroots innovations into the public domain, attracting attention from investors, policymakers, and collaborators. By amplifying voices that have traditionally been marginalized, technology can help democratize innovation.

Toward an Inclusive Innovation Ecosystem

Building an inclusive innovation ecosystem requires coordinated efforts across policy, institutions, and communities. Expanding access to funding through micro-venture funds and grants is essential, particularly for early-stage and high-risk innovations. Strengthening rural incubation networks can provide localized support, making innovation more accessible.

Capacity building remains a priority. Women need access to skills, tools, and networks that enable them to translate ideas into impactful solutions. Community-based innovation spaces, such as self-help groups, local labs, and training centres can play a crucial role in fostering collaboration and experimentation.

Policies recognize the unique challenges faced by women innovators and provide targeted support mechanisms. Public-private partnerships can further enhance the reach and effectiveness of innovation programs, ensuring that resources are distributed more equitably.

Redefining the Future of Innovation Building an Inclusive Ecosystem

India stands at a pivotal moment in its innovation journey. With a rapidly advancing technological ecosystem and a rich base of grassroots ingenuity, the country has the potential to redefine what innovation means in a global context. Women are at the heart of this transformation.

They are not just contributing to innovation, they are reshaping it. By bringing diverse perspectives, lived experiences, and a focus on inclusivity, women innovators are ensuring that technology serves broader societal goals. Their work demonstrates that innovation can be both cutting-edge and deeply human-centered.

The future of innovation will not be defined solely by technological sophistication, but by its ability to include, empower, and transform. By investing in women through education, access to technology, funding, and institutional support India can move toward a more inclusive and sustainable innovation ecosystem.

In this evolving landscape, women are not just participants they are leaders, creators, and visionaries. And in shaping the future of innovation, they are ensuring that progress is not only achieved, but shared.■

Dr. Kinkini Dasgupta Misra is a Scientist F at the Indian National Science Academy, Department of Science and Technology, New Delhi.
Email: kinkini.dst@gov.in

Building A Forest Digital Twin for India

Vidisha Kandpal, Hardev Choudhary

Introduction

Forests are invaluable assets that support both national development and environmental stability. They play a critical role in regulating climate, securing water resources, and sustaining biodiversity, while also supporting livelihoods, food security, and rural economies. By absorbing carbon and conserving soil, forests help reduce the impacts of climate change and protect agricultural and human systems. These ecological services form the foundation of ecosystems and settlements across the country, yet their true value is rarely reflected in conventional financial and economic accounting.

However, India's forests are under unprecedented pressure. Forest fires are increasing across several states, including Uttarakhand, Himachal Pradesh, Maharashtra, Odisha, and the Northeastern region, while climate change is altering rainfall patterns and intensifying drought stress.

Invasive species such as Lantana camara and Prosopis juliflora, along with rapid tourism growth, expanding infrastructure, mining, and fragmented land use, are placing growing strain on forest landscapes. Managing this complexity through periodic surveys and static maps is no longer sufficient, making digital transformation - and the concept of forest digital twins - increasingly critical.

A forest digital twin is a virtual representation of a real forest ecosystem that is continuously updated by incoming data. Unlike traditional forest maps that capture conditions at a single point in time, a digital twin evolves along with the forest (1, 2). The main components of a forest digital twin can primarily comprise of the data, which covers data acquisition to processing steps, second is model that includes creating 3D models and doing the simulations, and the third is evaluation, analysis and visualization. Data for a forest digital twin originate from multiple streams that connect the real forest to its digital counterpart, including IoT (Internet of Things) sensors monitoring trees, soil, climate, and wildlife; remote sensing technologies such as drone-based LiDAR (Light Detection and Ranging) that capture three-dimensional forest structure and biomass; satellite imagery that tracks vegetation health and land-use change; flux towers measuring carbon, water, and energy exchanges; and field-based observations such as forest inventories and management records. Based on these integrated data, models of forest ecosystems are developed to form a forest digital twin that can be remotely observed, analysed, and simulated, enabling virtual testing of scenarios such as assessing forest fire risks before they occur and supporting informed forest management and policy interventions in advance (3, 4).

For India, such a system could be transformative. India's forests are highly diverse, and different ecosystems respond differently to environmental stress, making uniform management approaches less effective. Forest digital twins can capture this complexity dynamically and support ecosystem specific decision making. One of the most immediate applications lies in fire management, where integrated data from historical fire records, satellite dryness indices, LiDAR-based fuel load estimates, and acoustic sensors can enable early risk identification and proactive prevention. Another application is the management of forest carbon through the provision of up-to-date and reliable records of carbon storage. This enables easier tracking of changes, accurate reporting, and better support for climate targets and carbon trading. Biodiversity monitoring can be enhanced through eco-acoustic sensors and artificial intelligence, allowing non-invasive tracking of

India's forests are under unprecedented pressure. Forest fires are increasing, while climate change is altering rainfall patterns

species presence and ecosystem health. In forest restoration, digital twins enable virtual testing of regeneration strategies under varying rainfall, soil moisture, and invasive species scenarios, improving long-term outcomes. This approach can also be used in agroforestry, where digital twins help farmers make better decisions like managing tree canopies, using water efficiently, coordinating crops, and boosting carbon storage. Forest digital twins can significantly strengthen biodiversity conservation by enabling integrated monitoring of species, habitats, wildlife movement, and behavioural patterns using sensors, AI (Artificial Intelligence), and geospatial data. This supports better protection of critical habitats, improved management of human-wildlife conflict, and more informed conservation planning.

India is not starting from zero in harnessing technology for forest management. The country already possesses strong technological foundations through Indian Space Research Organisation (ISRO)'s satellite platforms such as Resourcesat-2/2A and Cartosat-2/3, along with international datasets from NASA (National Aeronautics and Space Administration) and ESA (European Space Agency), including Sentinel-1/2/3, Landsat-8/9, and MODIS (Moderate Resolution Imaging Spectroradiometer), accessed through platforms like Bhuvan. The Forest Survey of India (FSI) regularly generates national forest assessments and fire alerts using these data streams, while drones are increasingly used by forest agencies for plantation monitoring, fire damage assessment, and restoration planning. Broader initiatives such as the Kisan Drone scheme and the NAMO Drone Didi scheme, though agriculture-focused, are expanding India's drone infrastructure, skills, and regulatory readiness, which can be leveraged for forestry applications (5,6). An important step in this direction was taken last year when Government of Rajasthan launched DigiVan, the country's first comprehensive state-level digital forest portal, integrating geospatial data, plantation records, species information, monitoring tools, and administrative workflows into a unified digital forest stack (7). Building on such platforms, forest digital twins can be developed as state-specific or ecosystem-based models that reflect the biodiversity and ecological conditions of different regions, while remaining interoperable within a broader national framework. Institutions such as the FSI, ISRO's National Remote Sensing Centre, the Wildlife Institute of India, the Indian Council of Forestry Research and Education (ICFRE) and research hubs within IITs and IISERs are well placed to lead India's transition toward forest digital twins. State forest departments, along with drone and LiDAR service providers, GIS firms, conservation NGOs such as WWF (World Wide Fund for Nature)- India, WCS (Wildlife Conservation Society)- India, ATREE (Ashoka Trust for Research in Ecology and the Environment), and the Nature Conservation Foundation, and emerging bioacoustics and geospatial start-ups including SatSure, Pixxel, ideaForge and Garuda Aerospace, together form a growing national capability. Despite this promise, key challenges remain, as data collected by different agencies often follows varying standards and formats, advanced technologies such as drone-based

AI generated image

India is not starting from zero in harnessing technology for forest management. The country already possesses strong technological foundations.

LiDAR remain costly, and remote forest areas face constraints related to power, connectivity, and sensor maintenance. Capacity building is equally critical, as digital forestry requires personnel trained not only in data collection but also in interpreting AI-driven insights for informed decision-making and effective scaling.

A pragmatic path forward is to start with carefully designed pilot projects across representative forest landscapes.

Beyond technical barriers, governance and ethics raise important questions. As forests become increasingly digitised, questions of data ownership and access become more important. Who controls forest digital data - the state, local communities or technology providers? How can traditional knowledge be protected while embracing digital documentation? How can monitoring tools be used responsibly without creating surveillance concerns? These questions must be addressed early to ensure that digital forestry remains inclusive, transparent and socially responsible. At the same time, while India's Biological Diversity Act, 2002 addresses access and benefit-sharing of biological resources, it provides limited direction on the governance and protection of large-scale digital biodiversity data. Explicit data protection and access safeguards within forest digital twin frameworks are therefore essential to prevent misuse and ensure ethical, transparent conservation.

A pragmatic path forward is to start with carefully designed pilot projects across representative forest landscapes. A national forest digital twin framework, led by the Ministry of Environment, Forest and Climate Change in collaboration with FSI and ISRO- including North Eastern Space Applications Centre (NESAC)'s drone-based imaging initiatives could standardise protocols and data architecture. Engaging local communities and youth in data collection and validation will ensure that innovation remains grounded in local realities.

Forest digital twins are no longer science fiction. They represent a new stage in forest management by combining LiDAR-based measurements, acoustic monitoring of biodiversity, climate model projections, and the knowledge of forest dependent communities. As pressures on India's forests intensify, the need for integrated, real time and forward looking management systems becomes unavoidable.

India is at a critical juncture. It can either develop these systems early and shape their direction, or delay adoption and lose the opportunity to lead.

The real question is not whether India has the capability to build forest digital twins- it is when the country will take its first decisive step.■

References

1. Qiu, H., Zhang, H., Lei, K., Zhang, H., & Hu, X. (2023). Forest digital twin: A new tool for forest management practices based on spatio temporal data, 3D simulation engine, and intelligent interactive environment. Computers and Electronics in Agriculture, 215, 108416. https://doi.org/10.1016/j.compag.2023.108416
2. Döllner, J., de Amicis, R., Burmeister, J.-M., & Richter, R. (2023). Forests in the digital age: Concepts and technologies for designing and deploying forest digital twins. In Proceedings of the 28th International ACM Conference on 3D Web Technology (Web3D '23) (pp. 1–12). ACM. https://doi.org/10.1145/3611314.3616067
3. Buonocore, L.; Yates, J.; Valentini, R. A Proposal for a Forest Digital Twin Framework and Its Perspectives. Forests 2022, 13, 498. https://doi.org/10.3390/f13040498
4. ATT Inc. (n.d.). Digital Twins in Forest Management: Revolutionizing Conservation and Sustainability. Retrieved January 19, 2026, from https://www.attinc.com/news/digital-twins-in-forest-management/
5. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2204751
6. https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1909215
7. https://forest-stack.digivan.forest.rajasthan.gov.in/

Dr. Vidisha Kandpal is working as Senior Fellow and associated with VARD & IPM- Agriculture, National Innovation Foundation- India. She holds PhD in Forest Botany from Forest Research Institute, Dehradun.
Email: vidishak@nifindia.org

Mr Hardev Choudhary is Scientist-E at National Innovation Foundation- India. He has research experience in agriculture innovation and leads VARD & IPM- Agriculture division.
Email: hardev@nifindia.org

Tick control measures and significance of ethnobotanicals for livestock health system

Smita Ramkumar, Hiral Gadhavi, and Ravikumar R K

Introduction

Ticks are from the Ixodidae family, act as ectoparasites, causing loss to livestock sector due to host blood loss, transmission of pathogens along with welfare issues like overall discomfort, and irritation. These parasites cause adverse effects through decrease in feed intake, immune system suppression, and harm to hides [Obaid et al., 2022]. Globally, livestock sector is paramount for food security, provide economic support among farming communities for social wellbeing. Tick control become a critical health constraint as it is widely prevalent. It is to be acknowledged that the agricultural system is strongly influenced by culture and any technological intervention need to be oriented within this predilection. There is need to improvise measures to overcome tick resistance and minimize chemical usage in this health service. Creating awareness of improved farming practices or enhancing availability of sustainable technologies can minimise risk in agricultural food systems and associated challenges to environment.

Health care challenges in control of tick infestation:

In most regions, worldwide, large-scale control of tick infestation is held with support of livestock institutions and these approaches rely heavily on chemical acaricide. These chemicals include Arsenic, which was the first widely used compound against tick, later replaced by chlorinated hydrocarbons due to development of resistance. The high toxicity nature of chlorinated hydrocarbons led to its withdrawal from livestock health service. By 1950, Organophosphorous compounds become mainstay due to its impact on ectoparasites in low concentration [Costa, 2018]. However, these compounds are also confronted with toxicity and recommended application of this technical knowhow need to be carefully adhered. Inorder to avoid any untoward incident on animal welfare, such recommendations were examined at regular intervals and precautions were referred. Further, during registration of commercial products for regulatory clearance, procedures for safe application of these chemical products have to be enlisted.

With these challenges, farmers try different measures within the available treatment strategies either by application of overdose or mix different available choice of acaricides. These form of application(s) tend to develop acaricide resistance posing major threat to livestock health. Frequent and indiscriminate use of acaricides can lead to reduction in tick susceptibility to these compounds, causing subsequent failure to control ticks. This had led to development of resistance in each of the category of chemical acaricides. Efforts have to be intensified in management of recurrent tick infestation by identifying technologies or product that can address existing limitations within the context of farming system.

Development of resistance aggravates challenges in managing tick and limits ability in control of Tick-Borne Diseases (TBDs) like babesiosis. This results in reduced productivity and increase in treatment cost. Technologies have to be reinforced to reduce farmers' dependence on chemicals by utilization of environmental friendly practices. This can assist farming system by reducing input cost, strengthening alternative solution, their continued supply and encourage self-reliance. In this respect, herbal practices or ethnobotanicals reflect a deep understanding of local biodiversity and its potential role in animal health, productivity system. These practices are valuable in rural and resource-limited settings wherein access to commercial veterinary inputs are limited.

They are often easier to adopt and helps to sustain responsible farming system. The soil biology can be protected by minimizing chemical residue, which has been the major practice by few decades. Recognizing these

interconnections, development of ecologically viable technological solutions and transdisciplinary approach helps to reinforce principles of One Health. Policy intervention suggest deployment of eco-friendly technologies to mitigate ectoparasite infestation. It is essential to explore usefulness of societal knowledge based on ethnobotanicals across different parts of the world.

Indigenous knowledge system in reference to control of tick infestation:

Different communities deploy herbs by understanding their functional properties for human, veterinary ailments. People tend to identify botanicals which are available nearby or wild and make use of it. Several of these herbal practices are maintained by community and relate usefulness of ethnobotanicals, their plant parts, method of preparation. This crucial interface between knowledge of community and belief established through their observations assist in providing health care for ailments through outstanding herbal practices.

It is essential to appreciate that several of herbal practices exist across different communities and necessary approaches have to be unearthed towards mainstreaming community oriented knowledge system. This paper illustrates few of the most common ethnobotanicals that are in practice in control of ectoparasite and nature of involvement of veterinary institutions in refinement, utilization of knowledge system such insights. The common ethnobotanicals in control of tick infestation includes *Azadiracta indica*, *Vitex negundo L* in Asia, *Cleome gynandra L.*, *Ricinus communis* in Asia and Africa, *Lippia javanica* in Africa, *Ambrosia peruviana All* in South America and *Annona squamosa* L in North America & Asia [Table 1]. Phytochemicals and their associated functional role of these herbs indicate the contributing antiparasitic properties. These principles of acaricidal or repellent properties lend credibility in their usage by community towards control of tick infestation. These practices are pertinent as they are sustained by society over period in respective regions of the world. Each geographical regions are bestowed with ethnobotanicals that had indicated usefulness in tick control measures.

Scaling of polyherbal acaricide through institutional involvement:

In various stages, efforts are being conducted to appreciate their efficacy and way to transfer this rich repository of knowledge in meeting health care need. Planners and institutions are exploring means to involve livestock farmers in technology demonstration so as to address health care challenges. Among several approaches, insitu value addition of traditional practices at community level is a desirable step that can aid in preservation, utilization. Few of herbal formulations based on community knowledge were assessed against natural infestation and efficacies were demonstrated (Nimbalkar et al., 2020).Usefulness of a standardized preparation involving neem (*Azadiracta indica*) and nagod (*Vitex negundo*) in management of ectoparasite was shared (PIB, 2022). Efficacy were observed in studies conducted in Gujarat, Himachal Pradesh, Karnataka, Tamil Nadu, Uttar Pradesh, Haryana (NIF-KVASFU, 2022). This had helped to popularize the technology with the support of Agriculture/ Veterinary Universities, State Animal Husbandry Departments, Dairy Cooperatives and Krishi Vigyan Kendra [KVK]. Front line demonstration(s) were conducted involving farmers for sustaining, scaling up of this community knowledge. These inter-institutional government cooperation is essential as livestock sector is predominantly influenced by public sector. An empirical study was conducted by KVK –Rastakuntubai, Acharya NG Ranga Agricultural University, Andhra Pradesh involving this preparation against natural infestation. This study demonstrated about 80 percent reduction in tick infestation by 3rd day and about 90 percent reduction by 7th day of post treatment (Gopalakrishnan et al., 2026). Case studies conducted by KVK-Theni -TNUVAS indicated usefulness of this technology in farmer field (Senthilkumar, 2023). This had facilitated technology transfer intervention by KVK's to dairy farmers for wider utilization across the country.

Adoption of best practices require comprehensive approach in influencing livestock owner's decision making process. The farm operation depends on multiple factors and management of tick is one among the health issues to be addressed. These studies reinforce that ethnobotanicals are environment friendly and exploiting them (plants and plant products) represents a promising approach. Livestock farmers need to be convinced with the problem, to know the expected advantage by taking up the solution. This methodological approach involving ethnobotanicals

SN	Plant	Family	Predominent continent distribution	Major phytochemicals	Associated properties	References
1	*Azadirachta indica Juss*	Meliaceae	Asia	Azadirachtin, Nimbin	Antifeedant, larvicidal, ovicidal, repellent action, growth deregulation, reduction in ecdysone levels, alterations in development and reproduction, sterility	Gareh et al., 2022,
2	*Vitex negundo L*	Verbenaceae	Asia	Vitexin, iso vitexin, luteolin derivatives	Acaricidal, ovicidal against oligonychus coffeae	Banerjee et al., 2021 Phate and Patil, 2026
3	*Cleome gynandra L.*	Cleomaceae	Asia and Africa	β-sitosterol, Kaempferol	Repellent and acaricidal properties	Nyalala and Grout, 2007 Adhikari and Paul., 2018
4	*Ricinus communis L.*	Euphorbiaceae	Asia and Africa	Gentisic acid, Catechin	Acaricidal, larivicidal, insecticidal	Gosh et al., 2013 Ghnimi et al., 2014
5	*Lippia javanica (Burm.f.) Spreng.*	Verbenaceae	Predominently in Africa	Linalool, Geranial	Acaricidal properties	Madzimure et al., 2011, Maroyi, 2017
6	*Ambrosia peruviana All*	Asteraceae	South America	Curcumene, Chrysanthenone	Acaricidal, repellent property, larvicidal, oviposition inhibition	Guzmán et al., 2022
7	*Annona squamosa L*	Annonaceae	North America and Asia	Annonaceous acetogenins	Insecticidal activity, acaricidal activity, larvicidal activity	Madhumitha et al, 2012 Wanzala, 2017

illustrate an intervention or replicable model of translating technological solution to actual practice from societal knowledge.

This working example demonstrate a model of utilization of common ethnobotanicals available in different parts of the world. These inherent knowledge system have to be examined by stakeholders by embracing suitable measures to address local needs, invest in existing skill, indigenous knowledge of farming communities. This compatible technological alternatives can assist in timely intervention of health service, create enthusiasm among adopters and promoters in agrarian value chain, farming system.

Conclusion:

Herbal practices provide accessible and low-cost alternatives to chemical treatments, also reinforce cultural traditions, community-based knowledge sharing. An integrated framework reduces the risk of chemical resistance in tick populations and promotes a more holistic livestock health system that aligns with ecological sustainability, rural socio-economic realities.

Further this wealth of knowledge have to be protected for long term utilization. In this respect, systems have to be augmented in sustaining these outstanding traditional knowledge practices.■

References

Adhikari, P. P., & Paul, S. B. (2018). Medicinally important plant *Cleome gynandra*: A phytochemical and pharmacological explanation. Asian Journal of Pharmaceutical and Clinical Research, 11(1), 21–29.

Banerjee, P., Laha, A., Samaddar, I., Biswas, H., Sarkar, D., Roy, S., Saha, G. K., & Podder, S. (2021). Acaricidal activity of nishinda (*Vitex negundo L*) leaf and garlic (*Allium sativum*) bulb extract against red spider mite, *Oligonychus coffeae* (Acari: Tetranychidae) in tea plantations of Darjeeling Hill, West Bengal, India. Journal name, 65(1), 59–64.

Costa L. G. (2018). Organophosphorus Compounds at 80: Some Old and New Issues. Toxicological sciences: an official journal of the Society of Toxicology, 162(1), 24–35.

Gareh, A., Hassan, D., Essa, A., Kotb, S., Karmi, M., Mohamed, A. E.-H. H., Alkhaibari, A. M., Elbaz, E., Elhawary, N. M., Hassanen, E. A. A., Lokman, M. S., El-Gohary, F. A., & Elmahallawy, E. K. (2022). Acaricidal properties of four neem seed extracts (*Azadirachta indica*) on the camel tick *Hyalomma dromedarii* (Acari: Ixodidae). Frontiers in Veterinary Science, 9, 946702.

Ghnimi, W., Dicko, A., Khouja, M. L., & El Ferchichi, O. H. (2014). Larvicidal activity, phytochemical composition, and antioxidant properties of different parts of five populations of *Ricinus communis L.* Industrial Crops and Products, 56, 43–51.

Ghosh, S., Tiwari, S. S., Srivastava, S., Sharma, A. K., Kumar, S., Ray, D. D., & Rawat, A. K. S. (2013). Acaricidal properties of *Ricinus communis* leaf extracts against organophosphate and pyrethroids resistant *Rhipicephalus (Boophilus) microplus*. Veterinary Parasitology, 192(1–3), 259–267.

Gopalakrishnan, A., Veena, G. A., Jyothi, Y. U., S., Sravanthi, S., Vihari, M. A., Raju, S. S., & Dhurua, S. (2026). Evaluation of poly herbal extract from *Azadirachta indica* (Neem) and *Vitex negundo* leaves for the control of ectoparasitic infestation in bovine. International Journal of Veterinary Sciences and Animal Husbandry, 11(2), 432–434.

Guzmán, L., Malla, J. L., Ramírez, J., Gilardoni, G., Calva, J., Hidalgo, D., Valarezo, E., & Rey-Valeirón, C. (2022). Acaricidal Efficacy of Plants from Ecuador, *Ambrosia peruviana* (Asteraceae) and *Lepechinia mutica* (Lamiaceae) against Larvae and Engorged Adult Females of the Common Cattle Tick, *Rhipicephalus microplus*. Veterinary Sciences, 9(1), 23.

Madhumitha, G., Rajakumar, G., Roopan, S. M., Rahuman, A. A., Priya, K. M., Saral, A. M., Khan, F. R., Khanna, V. G., Velayutham, K., Jayaseelan, C., Kamaraj, C., & Elango, G. (2012). Acaricidal, insecticidal, and larvicidal efficacy of fruit peel aqueous extract of *Annona squamosa* and its compounds against blood-feeding parasites. Parasitology research, 111(5), 2189–2199

Madzimure, J., Nyahangare, E.T., Hamudikuwanda, H., Hove, T., Stevenson, P.C., Belmain, S.R. and Mvumi, B.M. (2011) Acaricidal Efficacy against Cattle Ticks and Acute Oral Toxicity of *Lippia javanica (Burm F.) Spreng*. Tropical Animal Health and Production, 43, 481-489.

Maroyi A. (2017). Lippia javanica (Burm.f.) Spreng.: Traditional and Commercial Uses and Phytochemical and Pharmacological Significance in the African and Indian Subcontinent. Evidence-based complementary and alternative medicine: eCAM, 2017, 6746071.

NIF-KVAFSU (2022). Quality livestock service through in-situ value addition of indigenous knowledge: An approach to control tick infestation, Policy brief, National Innovation Foundation-India, Gandhinagar and Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar. pp 1-8.

Nimbalkar, S. D., Patil, D. S., & Deo, A. D. (2020). Ethnoveterinary practices (EVP) for control of ectoparasite in livestock. Indian Journal of Traditional Knowledge, 19(2), 401–405.

Nyalala, S., & Grout, B. (2007). African spider flower (*Cleome gynandra L./Gynandropsis gynandra (L.) Briq.*) as a red spider mite (*Tetranychus urticae Koch*) repellent in cut-flower rose *(Rosa hybrida L.*) cultivation. Scientia Horticulturae, 114(3), 194–198.

Obaid, M. K., Islam, N., Alouffi, A., Khan, A. Z., da Silva Vaz Jr, I., Tanaka, T., & Ali, A. (2022). Acaricides resistance in ticks: selection, diagnosis, mechanisms, and mitigation. Frontiers in Cellular and Infection Microbiology, 12, 941831.

Phate, P. V., & Patil, A. S. (2026). *Vitex negundo Linn.*: A decade of advances in phytochemistry, pharmacological activities, and biotechnological interventions (2015–2025)—A comprehensive review. Phytomedicine, 153, 157895.

PIB, 2022. Polyherbal eco-friendly technology can combat tick infestation among dairy animals. https://pib.gov.in/PressReleasePage.aspx?PRID=1810576

Senthilkumar, S. (2023). Effectiveness of NIF-polyherbal medication to control ticks in dairy cattle: Case study. In Proceedings of the International Conference on Global Perspectives in Ethnoveterinary Herbal Research for Production of Residue-Free Animal Products (pp. 91–93). Veterinary College and Research Institute, Orathanadu, Thanjavur, TANUVAS, Tamil Nadu, India.

Wanzala, W. (2017). Potential of traditional knowledge of plants in the management of arthropods in livestock industry with focus on (Acari) ticks. Evidence-Based Complementary and Alternative Medicine, 2017, 1–33.

Ms. Smita Ramkumar, Junior Associate is associated with VARD & IPM – Human Health & Veterinary Division at NIF-India. She holds a Master's degree in Microbiology.
Email:smitar@nifindia.org

Dr. Hiral Gadhavi, Research Associate-I is associated with VARD & IPM – Human Health & Veterinary Division at NIF-India. She holds a PhD in Botany from Gujarat University, Ahmedabad.
Email:hiralg@nifindia.org

Dr. R K Ravikumar is Scientist 'F' at National Innovation Foundation – India. He holds doctorate degree from the Indian Veterinary Research Institute [IVRI] and is recipient of NASI – Platinum Jubilee Award in Biological Sciences, 2022. Dr. Ravikumar leads Value Addition Research and Development & Intellectual Property Management (VARD & IPM)- Human Health & Veterinary Division.
Email: ravikumar@nifindia.org

Hindi as India's Secret Innovation Engine

Nitin Maurya, Ganesh Chandra

Introduction

For decades, the global technology ecosystem has been largely shaped by the English language, owing to its international acceptance and widespread usage. While English offers broad reach, it also carries inherent linguistic complexities—such as silent letters (for example, the k in knife or gh in thought) and irregular vowel pronunciations (the letter o sounding differently in go, do, and women, or u in put versus but). These inconsistencies pose challenges for standardization, learning, and precise machine interpretation.

In today's digital era, where innovation prioritizes efficiency, inclusivity, and seamless machine compatibility, such complexities become increasingly significant. In this context, Hindi—with its phonetic and rule-based "scientific script"—is gradually emerging as a powerful digital language. Its consistent sound–symbol relationship enhances readability, speech recognition, and computational processing, positioning Hindi as an effective bridge between cultural heritage and modern technology in the evolving digital landscape.

1. The "Logic Advantage": What You See is What You Say

In AI development, the biggest challenge with English is teaching a machine the thousands of exceptions to spelling rules. On the other hand, Hindi is a phonetic language written in the Devanagari script, meaning that each written character corresponds exactly to its spoken sound. This clear logic helps drive modern innovation:

For machines, Hindi's predictability enhances AI (Artificial Intelligence) performance, making it well-suited for accurate speech-to-text and Natural Language Processing (NLP), which allows computers to understand and process human language. This predictability also makes the development of Automatic Speech Recognition (ASR) systems, which convert spoken language to text, mathematically easier.

Now, modern digital tools are slowly changing this. Accessing and sharing information in Hindi and other regional languages has increasingly become possible.

For people, it makes learning to read much easier. In the 21st century, when rapid upskilling is necessary, the phonetic nature of Hindi enables people to transition from "learning to read" to "reading to learn" much more quickly than in languages with irregular orthography (the system of spelling in a language).

2. The Rise of Voice-First Technology

One of the biggest technology changes today is moving from typing to speaking. For most people in India, using a keyboard is difficult, but speaking comes naturally.

Hindi is organized in a scientific way, based on how sounds are made in the mouth. This structure is similar to the logic of computer programming. As a result, Hindi voice assistants and transcription tools are more reliable. They are especially useful for medical dictation, legal records, or government services.

3. Democratizing the "Bharat" Startup Ecosystem

A country grows with innovation, and an innovation grows with participation. About a decade or so ago, millions of creative people in India's heartland were left out because they did not speak English - the "language of the internet."

Now, modern digital tools are slowly changing this. Accessing and sharing information in Hindi and other regional languages has increasingly become possible. Artificial Intelligence, Machine Learning, and Natural Language Processing together are shaping this movement of "mass innovation".

Developing Hyper-Local Solutions - The next big Indian startups focus on "Bharat"—

the Hindi (and other regional languages) speaking areas outside big cities. Fintech apps are improving access to finance, agritech apps are helping farmers with timely access to information and markets, and edtech platforms are teaching complex

topics in the local languages. The entrepreneurs are beginning to solve problems unique to a region and to India as a whole.

Driving Frugal Innovation - When a technology uses people's own language, it encourages local creativity and innovation. Now, a mechanic in a small town can learn global engineering ideas through Hindi tutorials, and a farmer can learn to protect crops using local plants and become an experimenter. This leads to simple, affordable local solutions for local problems, which may (or may not) have potential for scaling up regionally, nationally, or globally.

4. The growth of the Creative Economy

Riding on the advances in technology, innovation is also about storytelling. With digital streaming, Hindi creators are trying different genres and realistic stories. This has made India a global centre for post-production and digital storytelling. This has resulted in the emergence of local creative talent, which has built a multi-billion-rupee industry standing on the Hindi language and culture.

AI generated

The Road Ahead

As human-machine interfaces transition from touch-based to voice-based systems, the phonetic advantages of Hindi will become increasingly prominent. The Hindi alphabet is systematically organized by place of articulation, beginning with guttural sounds produced in the throat and progressing to labial sounds formed at the lips. Ongoing advancements in artificial intelligence will leverage the mathematical precision of Devanagari for more efficient data processing. By capitalizing on these intrinsic features, India is not merely participating in global innovation but is also redefining its parameters, demonstrating that ancient scientific scripts can drive contemporary technological progress and empower millions to contribute to the 21st century. ■

References:
[i] www.meity.gov.in/static/uploads/2025/10/8e40cdd134cd92dd783a37556428c370.pdf, retrieved on Dec 31, 2025
[ii]https://apastyle.apa.org/blog/cite-generative-ai-references, retrieved on Dec 31, 2025
[iii] https://style.mla.org/citing-generative-ai/, retrieved on Dec 31, 2025

Dr. Nitin Maurya is a Scientist – E and leads the Dissemination and Social Diffusion (DSD) Department at the National Innovation Foundation – India. He also Chairs the Rajbhasha Committee at the institution.
Email: nitin@nifindia.org

Shri Ganesh Chandra serves as the Manager (Rajbhasha) at the National Innovation Foundation – India, where he oversees all Rajbhasha related activities.
Email: ganeshc@nifindia.org

Innovation in the Hills: Exploring Grassroots Creativity in Assam and Nagaland

Sayantan Dhar, Kartik Patel, Rajiv Mili and Vivek Kumar

In a country often driven by high-tech breakthroughs and urban innovation hubs, a quiet yet powerful movement unfolded in early 2026 across the landscapes of Assam and Nagaland. NIF organized an Innovation Yatra from Kamrup, Assam to Nuiland, Nagaland from January 29 to February 15, 2026, to identify, document, disseminate, and strengthen grassroots innovations and traditional knowledge systems in remote regions of Northeast India.

One machine, endless possibilities

The journey began on 29 January in Bakrapara village, Kamrup district, Assam, with a demonstration that perfectly captured the spirit of grassroots innovation. A paddy straw cutter, designed for mushroom cultivation, addressed a common but overlooked problem faced by farmers, the time-consuming preparation of straw for mushroom beds. Traditionally, this work requires long hours of manual labour, often carried out by women.

The machine transformed this process. With the ability to process up to 1,200 bundles per hour, it reduced physical strain, improved efficiency, and increased productivity. For over 50 women farmers who participated in the training session, it was not just a tool, it was an opportunity to enhance their livelihoods.

The winter sun had barely risen over Bakrapara village in Assam when a group of women gathered around a humming machine. Their attention was fixed, not just on the spinning blades of a paddy straw cutter, but on what it promised.

For years, preparing straw for mushroom cultivation meant hours of labour. Then came the machine. Developed by Odisha-based innovator Ajay Kumar Prusty, the paddy straw cutter demonstrated how a simple idea could transform livelihoods.

For over 50 women farmers who participated in the training session, it was not just a tool, it was an opportunity to enhance their livelihoods.

"For women farmers, this significantly reduces drudgery and saves time," Team NIF-India explained during the session, highlighting how the machine can process large volumes efficiently. Nearby, farmers watched closely as bundles of neatly cut straw piled up, work that once took hours now completed in minutes.

Beyond Machines: Knowledge that lives in memory

Yet, the Yatra was not solely about introducing new technologies. It was equally about listening. On the very first day, local herbal practitioners shared traditional remedies for ailments ranging from joint pain to digestive disorders. A bamboo artisan demonstrated skills passed down through generations. This

A grassroots innovation by Ajay Kumar Prusty brings efficiency to mushroom cultivation at Bakrapara, Rani under Kamrup District, Assam.

blend of modern innovation and indigenous knowledge became the defining feature of the journey.

As the team moved towards villages near Kaziranga National Park, evening gatherings turned into vibrant platforms for exchange. Farmers, students, and workers came together to witness demonstrations of practical innovations, fruit harvesters, load-reducing devices, and mobility aids designed for uneven terrain. These were not complex machines, but simple solutions to everyday challenges.

A glimpse of participants gathered at Chare Village, Tuensang District, Nagaland, during the Grassroots Innovation Sensitization Program.

What stoodout was the immediate connection people felt. Many villagers recognized their own struggles in these innovations. In return, they shared their own knowledge, herbal treatments for asthma and fractures, and organic farming practices refined over time. Even in remote settings, the enthusiasm was unmistakable.

Young Minds, new possibilities

"We encourage students to identify problems in their surroundings and think of solutions," said a programme facilitator, referring to national innovation initiatives. The second day shifted focus to education in Golaghat district, a girls' school at Furkating G.J. Balika Vidyalaya, students encountered a new way of thinking. Hundreds of students participated in an awareness programme on innovation. For many, it was a moment of realization: innovation is not limited to laboratories or scientists. For many students, this was a turning point. Innovation no longer seemed distant, it felt achievable. It can begin with observing everyday problems and thinking creatively about solutions. The idea that they, too, could become innovators sparked curiosity and confidence.

Into the Hills: Local Innovators take the lead

Crossing into Nagaland, the Yatra continued to bridge gaps between remote communities and institutional support systems. In Sungro town and Tsarü village, interactions with farmers, teachers, and local residents led to the documentation of several grassroots innovations—particularly small tools for food processing and daily use.

Innovation Meets Sustainability

A key highlight emerged in Tuli village, where participants were trained to use a machine that converts areca-nut sheaths into biodegradable plates and bowls. This innovation demonstrated how agricultural waste can be transformed into eco-friendly products, opening avenues for rural entrepreneurship while addressing environmental concerns.

Participants saw potential for enterprise. "This can create income while reducing plastic waste," a local SHG member observed during the training.

Active participation of women farmers and local innovators in the Grassroots Innovation Sensitization Programme at Kiphire District Agriculture Office.

Across other villages, including Angangba and New Chingmei, the Yatra showcased a range of practical technologies such as fish dryers, paddy husk stoves, and multi-purpose agricultural tools. These innovations were not designed in distant labs, they were shaped by real needs, making them highly relevant and adaptable.

Interactive Meeting and demonstration of Grassroots innovations at Suhoi village of Niuland District in Nagaland

Kiphire: Ideas from the Margins

One of the most significant milestones was reached in Kiphire district, where the first Innovation Yatra in Nagaland brought together farmers, women entrepreneurs, youth, and officials. The event showcased several grassroots technologies and led to the identification of new local innovations. It highlighted an important truth: remoteness does not limit creativity; in many cases, it strengthens it.In Kiphire district, often considered remote, innovation was thriving.Innovator T. Litsakyu Sangtam displayed traditional tools including the Naga dao and improved agricultural implements."These tools have evolved over time to match our terrain and work patterns," he noted, pointing to their adaptability.

Ideas in the Cold

The journey then moved to Pfutsero, a high-altitude town known for its cold climate.

In Pfutsero, students presented ideas ranging from agricultural tools to energy-saving devices.

Their solutions were practical, rooted in local realities.

"They observe closely," a teacher noted. "That is where innovation begins."

Their ideas reflected a deep understanding of local challenges, proving that innovation can thrive even in the most challenging environments.

Closing Reflection: Where Innovation Truly Lives

The Yatra concluded in Suhoi village with discussions on entrepreneurship and ecosystem development. Participants explored how grassroots innovations could be supported through training, mentorship, and market linkages. The conversations underscored the importance of sustained engagement, because innovation does not end with an idea; it grows with support.

Over the course of the journey, dozens of grassroots innovations were documented, and hundreds of individuals engaged. But beyond these numbers lies a more powerful narrative.

In regions marked by difficult terrain and limited infrastructure, innovation is not optional, it is essential. Farmers adapt tools to suit steep slopes, artisans refine natural materials into functional designs, and communities develop solutions through experience and necessity. These innovations may not always be visible, but they are deeply impactful.

The Assam–Nagaland Innovation Yatra demonstrated that meaningful progress comes from recognizing and supporting such local ingenuity. By travelling directly to villages and schools, it reduced the distance between grassroots innovators and national platforms.

The experience offers an important lesson for the future: innovation ecosystems must be inclusive and decentralized. Instead of imposing solutions, institutions must learn to identify, nurture, and amplify ideas that already exist within communities.

As India moves forward on its path of development, such grassroots initiatives hold immense promise. They remind us that innovation is not confined to urban centres or advanced laboratories, it is alive in the fields, forests, and homes of rural India. Sometimes, the most powerful ideas are not invented, they are discovered.■

Mr. Sayantan Dhar is a Junior Fellow at the National Innovation Foundation – India. He holds Mater Degree in Botany and associated with Scouting, Documentation and Database Management (SDDM) Department.
Email: sayantand@nifindia.org

Er. Kartik Patel is a Senior Project Associate at the National Innovation Foundation – India. He holds Bachelor Degree in Agriculture-Engineering and associated with Value Addition Research and Development (VARD) Department.
Email: kartikp@nifindia.org

Dr. Rajiv Mili is a Principal Associate at the National Innovation Foundation – India. He holds a PhD in Botany and is associated with the Scouting, Documentation, and Database Management (SDDM) Department.
Email: rajivmili@nifindia.org

Dr. Vivek Kumar is Scientist – F and Head of Scouting, Documentation and Database Management Department at the National Innovation Foundation – India.
Email: vivekkumar@nifindia.org

राष्ट्रीय नवप्रवर्तन प्रतिष्ठान – भारत
विज्ञान एवं प्रौद्योगिकी विभाग, भारत सरकार का स्वायत्तशासी संस्थान
National Innovation Foundation - India
Autonomous Institute of the Department of Science & Technology, Govt. of India

National Innovation Foundation (NIF) - India
Headquarters: Grambharti, Amrapur, Gandhinagar-Mahudi Road, Gandhinagar, Gujarat, India – 382650
Camp Offices : Bhubaneswar (Odisha), Guwahati (Assam), Noida (Uttar Pradesh), Srinagar (Jammu & Kashmir).
Phone : Tel: +91-02764-261131, 32 | **Email :** newsletter@nifindia.org | **Website :** www.nif.org.in