Indian Farming 75 (08): 50-55; August 2025

Farm mechanization in northeast Indian hill agriculture

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Limited farm mechanization in the hill agriculture of northeast India resulted into low farm power availability (0.37–0.69 kW/ha). Steep hill slopes, fragmented land holding, poor infrastructure and limited connectivity hinders the technology dissemination process, resulting poor farm productivity. Affordable community centric farm mechanization efforts are essential to reduce labour cost, efficient input application, water conservation and post-harvest management of farmers' produce. High initial investment also bars the widespread adaptation of modern farm mechanization technologies. Establishment of community specific need based custom hiring centres, skill and technical expertise development among the rural youths with public financial support from public institutions became one of the most effective options to expand the future prospect of farm mechanization across northeast India.

Keywords: Custom hiring centre, Farmer income, Portable light weight machineries, Post-harvest, Skill development

DIVERSIFIED traditional subsistent farming systems with limited capacity for agricultural mechanization have epitomized the foundation of the local economy and daily rural livelihood of the native population of the northeast Indian hills. Complex accessible terrain features (lack of arable lands), limited infrastructure availability, and low adaptation rate of modern agricultural technologies have still added paramount difficulties to the region's struggle to shift from 'food deficit' to 'food surplus' status. In courtesy of rising food demand for nourishing the ever-increasing regional population and rapid urbanization trend in present days, the traditional agricultural production system needs to be evolved. Mechanization contributes to the diversification of Indian agriculture, shifting from traditional practices to the cultivation of commercial crops. The traditional crop production system of the northeast Indian hills relied heavily on human and animal labour and has significantly decreased over the years, traversing the rising scope of advanced farm mechanization suitable for hill agriculture. Farm mechanization enhances farming operations, decreases labour-intensive time-consuming tasks, reduces drudgery, boosts output, and raises farmers' profit. Nevertheless, the present status of agricultural farm mechanization in India is approximately 40–45%, compared to 95% in the United States and 75% in Brazil, indicating that India continues to lag far behind the developed nations in farm mechanization.

The Government of India (GoI) facilitates agricultural mechanization, viz. tractors, power tillers, combine harvesters, irrigation pumps, plant protection devices, threshers, improved implements, and hand tools, etc. through Sub-Mission on Agricultural Mechanization (SMAM) initiative. In the Indian context, Punjab and Haryana have the highest Farm Power Availability (FPA) of 6 KW/ha and 5.50 KW/ha, respectively, indicating highest adoption rate of farm mechanization against the least mechanized northeast Indian states. In contrast with the relatively higher farm power availability (kW/ha) in Tripura plains, steep undulated hills, rough terrain, limited communication service, and expensive transportation costs often contribute to the low mechanization status of India's north eastern hill region. Furthermore, the small, localized, and scattered farm holding increases

difficulties in implementing and adapting readily available large-scale automation options across the other mainland Indian states.

Table 1. Farm power availability and electrification status (rural and urban) in different northeast Indianstates

Sl. No	States	Farm power availability (kW/ha)
2.	Arunachal Pradesh	0.57
3.	Meghalaya	0.37
4.	Manipur	0.65
5.	Mizoram	0.68
6.	Nagaland	0.62
7.	Sikkim	0.69
8.	Tripura	1.63

Source: FICCI and PwC 2019, WAPCOS Limited 2020

Mechanization and availability of agricultural power, including mechanical, electric, and human and animal power, are closely associated. The proportional positive association between electricity availability and farm mechanization signifies an enormous opportunity for future expansion of small-scale, lightweight, and adaptable gear towards a potential increase in farm power availability, efficient farm labour management, meeting the location-specific farmer's demand, and associated skill development, particularly among the unskilled rural youths, in the highly electrified (100% rural and urban electrification; Ministry of Power 2022) north eastern hill states of India.

Unique challenges in mechanizing hill agriculture

Since the late 1960s, Green revolution banked on the critical role of promoting farm mechanization in India, helping to boost agricultural productivity through the adoption of high-yield varieties, irrigation facilities, and machine-based farming. In contrast, hill agriculture provides a number of unique problems that restrict the adoption and efficiency of technological automation. As compared to the highly mechanized lowlands where large-scale machinery can be easily deployed the harsh topography and socioeconomic conditions of hill areas make mechanization challenging. Mechanization is necessary to improve work efficiency, attending sustainability, and boost up agricultural production system through managing several labour-intensive seasonal farm operations likely, weeding, seedbed preparation, etc. in the high rainfall receiving summer/ rainy seasons, and conjunctive use of water during the winter months across the northeast Indian states. The accounted challenges for farm mechanization in north east Indian hills include:

- ***Steep slopes and difficult terrain:*** Conventional tractors and heavy mechanical machines are difficult for sloping fields because they might tip over, and the steep inclines make it difficult to operate huge motorized equipment efficiently.
- ***Small and scatter farm lands:*** The majority of hill farmers hold small terraced fragmented land, limiting the utilization of large-scale farming machines, mostly designed for flat lands. This demands the research needs to design location-specific small-scale farm machinery.
- ***High initial investment and limited financial access:*** Specialized machinery for hill agriculture, such as small horsepower (hp) power tillers and lightweight machinery, is costly. Furthermore, farmers sometimes lack access to loans or government subsidies to fund automated alternatives. Low farm profitability further discourages high investment in farm mechanization in hill agriculture.
- ***Limited infrastructure, regulatory network and road connectivity:*** Poor road connectivity, and inadequate regulatory framework in the hilly areas, makes transportation of farm machinery challenging. Moreover, the absence of adequate storage, maintenance and repair facilities further hinders the scope of farm mechanization in hill farming.
- ***Environmental risks:*** The use of heavy machinery often accelerates soil erosion or facilitates soil compaction from the use of heavy machinery in high-altitude locations having variable weather, making automated farming difficult. Heavy rains, landslides, and frequent climatic fluctuations exacerbate agricultural mechanization attempts.
- ***Limited community awareness,technically efficient and periodic availability of skill labour force:*** Limited sensitization on community-level usage of farm machinery, low skill, scarce availability of efficient labour force, and deformed extension services often discouraged the expansion of cultivatable land area and extensive adaptation of farm mechanization among the tribal farming communities of northeast India.

Farm mechanization in the hill agriculture system of northeast Indian hills

Despite increased mechanization, traditional farm implements remain popular in northeast India's hill regions due to their adaptation to the terrain and ease of use. These tools, which are predominantly powered by human or animal, are required for a variety of agricultural tasks, including land preparation, sowing, weeding, harvesting, and post-harvest processing. Modern small and lightweight farm machinery made expressly for hill agriculture contributes to overcoming the obstacles in hill farming systems by providing multipurpose options. These devices not only increase efficiency but also promote sustainable agriculture practices by reducing soil degradation and optimizing input utilization in hill agriculture.

The use of farm machinery appears critical for increasing agricultural output, lowering labour intensity, and boosting sustainability in hill regions. Because of the undulating topography, tiny and scattered landholdings, and unpredictable weather circumstances, traditional large-scale agricultural machinery is frequently unsuited for hilly terrains. Instead, lightweight, compact, and

adaptable technology suited to steep slopes and tiny terraces is required. Mechanization in hill agriculture improves field preparation, weed management, irrigation, harvesting, and post-harvest processing, resulting in greater efficiency and profitability for the farmers inhabiting the northeast Indian hills. However, the scope of extensive heavy farm mechanization in *Jhum* (shifting cultivation) fields of the northeast Indian hill region is limited to check soil erosion and ecological sustainability. Hence, small-scale hand-operated tools remain the most promising option in Jhum farming. However, the potential community-based farm mechanization options in low-lying paddy-based agriculture system remain economically profitable options for the farmers in the Lusei hills of Mizoram, Manipur, and Naga hills of the Patkai range, through a reduction in labour engagement for diverse farm operations, easing manoeuvrability and engaging versatile works. In Sikkim Himalaya, traditional organic agricultural practices are no longer sufficient to supply the demand for grains, pulses, and oilseeds. Being India's first organic state, farming is mainly carried out on terraced slopes, with very low farm power availability. The energy needed for agricultural operations increases as the slope percentage of the land increases. Therefore, mass-scale adaptation of improved crop cultivation methods and productivity enhancement through extensive need-based mechanization are at the topmost priority under the steep hill slopes and narrow terraces of northeast Indian hills. Our farm mechanization policy should aim to reduce the dependency on draught animals and human labour and promote community adaptation to mechanized hill farming. Some of the key benefits of farm mechanization in hill farming systems of northeast Indian states are summarized below:

- ***Managing labour-intensive tasks:*** In traditional crop cultivation, diverse farm operations, viz. ploughing, sowing, intercultural, harvesting-threshing, etc. require ample human labour engagement, boosting the rural economy. However, higher daily wages (₹500/day) often reduce farmers' profitability in northeast Indian hills. The extent of labour engagement and ploughing time requirement often depends on weed density and other field conditions in hill agriculture of northeast Indian hills. In Sikkim, controlling weeds is one of the most difficult issues in organic farming due to the state-imposed ban on conventional herbicides. Replacing traditional ploughing methods with a small power weeder can dramatically reduce labour needs, boosting weed management efficiency, soil aeration, and crop health. Lightweight models (35–40 kg), with continuous running hours (2.5–3.0 h) and adjustable handles are suitable for terrace

a b

c d

(a) Field demonstration of light weight power weeder (b) Use of chaff cutter in livestock farming (c) HDPE pipe lining for storage (d) Foliar spray of sea weed extract through manually operated sprayers in hill agriculture at Dzongu, North Sikkim

farming and can be easily transported from one terrace to another by 2–3 persons. Ploughing operation in 1-acre terraced land traditionally requires one pair of bulls and 3–4 labour engagements involving 7–8 hof continuous engagement with other recurrent expenses. In contrast, farm mechanization engaging mini power weeder led to a considerable reduction in labour intensity (>60%), time (~80%), and cost expenses (50%). However, ploughing of agricultural hilly lands with undulating topography (without terracing) accelerates soil erosion. Mechanical hand weeding becomes extremely labour intensive and time-consuming. Furthermore, mechanical weeders assist farmers in keeping weed-free fields and orchards with less manual labour; thereby enhancing productivity and sustainability in organic farming in Sikkim Himalaya.

- ***Precise application of agricultural inputs:*** Traditional land preparation techniques involving basal application of compost, manure, and biofertilizers are more labour-intensive, costly, and time-consuming in northeast India's mountainous regions. Traditional farmyard manure (FYM) and compost applications followed by fertilizers are spread manually over the fields engaging 4–5 labours/day in 1 acre of land area. Moreover, transporting bulky organic manure in up hills are labour intensive and facilitate uneven distribution, decreased soil fertility, and lower input use efficiency in hill agriculture. In hilly states like Himachal Pradesh, Uttarakhand, and Arunachal Pradesh, soluble fertilizers, synthetic pesticides, and herbicides are often applied using a knapsack sprayer which increases the risk for farmers due to prolonged exposure to chemicals. Farm mechanization using power sprayers and automated pesticide applicators facilitates uniform coverage, and reduce wastage and associated health risks. In organic states like Sikkim where chemical pesticides are not used, application of seaweed extract, neem-based, cow urine formulations, and microbial solutions are widely used for pest control. The application of bio-pesticides using power sprayers has brought significant benefits, resulting in higher soil fertility and better crops.
- ***Increased productivity and income:*** Mechanization increases cropping intensity, and crop diversification, and minimizes post-harvest losses in organic farming resulting in better farm incomes. The use of chaff cutters significantly reduces daily labour requirements in terms of work hours from one hour to 10–15 minutes for the preparation of 50 kg of livestock feed in a commercial animal-rearing venture in Sikkim Himalaya.
- ***Water conservation and efficient irrigation:*** The intensification of the winter water scarcity problem depends on the extent of adaptation for efficient water management techniques at both micro and mini-watershed levels. Motorized water pumping system may be useful to lift water from perennial streams in the low-lying river banks, while HDPE pipe-lining carrying gravity flow water from perennial streams and springs to the surrounding catchment areas of a watershed for optimization of seasonal water usage using sprinklers and drip irrigation systems in up-hill crop fields. In Sikkim, HDPE pipe lining for diversion-based irrigation systems from the perennial steam became an effective water management option in both micro and mini-spring sheds.
- ***Post-harvest processing through custom hiring centres:*** Higher cost involvement still hinders the extensive mechanization in the post-harvest processing and management sector of northeast Indian hills. The advantages of diversified farm products get nullified by the non-availability of post-harvest management, packaging, and storage facilities for the majority of perishable agricultural produce. Therefore, the relative contribution from north eastern hill agriculture to the local market economy is maintained; but reduces the competitiveness for the local farm products to an export-based free-global market economy.

Establishing village-level community-based custom hiring centres (CHCs) offers access to mechanical technologies for post-harvest processing and packaging towards reducing post-harvest losses and increasing the marketability of local farm produce through efficient market chain development. Small and marginal farmers inhabiting distant locations of remote tribal villages, lacking their financial means to invest in need-based equipment facilities, might get access to the community-based CHCs, as an alternative to effectively process their farm produce. Cluster-based CHCs established in the northeastern hill states under the Tribal sub Plan (TSP) projects of ICAR-NEH provided ample opportunities to the hill farmers in the mechanization for post-harvest processing, value additions, and marketing.

Technological innovations are still lagging in several sectors of post-harvest processing. In particular, the large cardamom is frequently grown on steep slopes without terracing in Sikkim; now rapidly expanding acreage in Nagaland and Arunachal Pradesh. However, post-harvest processing remained still challenging. The farmers compromise the quality of capsules processed through traditional bhattis that require less fuel. The enormous fuel consumption and time involved in processing large cardamom capsules using modified bhattis limits the large-scale adaptation among the tribal farmers of northeast India despite retaining good quality and preventing discoloration of final products. Eco-friendly biodegradable areca nut leaf plate making has substantiated future potential in agro-waste recycling and rural women empowerment, towards sustainable economic development across the lower Assam belts (including Mizo hills) of northeast India. Despite these benefits, the use of automation in the agriculture sector still confronts problems such as high prices, a shortage of tailored machinery, and limited farmers' knowledge. Government incentives, training, and location-specific

Combustion drying of large cardamom in (a) Traditional and (b) Improved bhattis at Dzongu, north Sikkim


Operational training on farm mechanization for the tribal Lepcha farmers at North Eastern Region Farm Machinery Training and Testing Institute in Bishwanath Charali, Assam

research are needed for widespread adaptation in hill agriculture. Community-based adaptation of hill-specific farm technology can assist in bridging the gap and encourage sustainable mechanized automated farming, even using drone technology.

Capacity building, skill and entrepreneurship development

The sustainability of farm mechanization and custom hiring centers (CHCs) requires supportive skill development programmes. The institutional support (ICAR, SAUs, etc.) on farm mechanization should be coupled with periodic technical training for capacity building and skill development of rural tribal youths. The North Eastern Region Farm Machinery Training and Testing Institute was established in Bishwanath Charali, Assam to develop competent skill-oriented human resources to facilitate farm mechanization in the northeast India. Unemployed educated rural youths should be trained for future widespread agri-entrepreneurship development.

Future prospects

The future prospect of expanding farm mechanization in hill agriculture is primarily dependent on planned interventions from public institutions that solve current mechanization issues in hill agriculture towards increasing productivity, sustainability, and economic feasibility of farm production. Several essential aspects must be targeted to guarantee that mechanization is widely adopted for NEH region in this direction:

Government subsidies and financial support:

- Increased government support and incentives for small and marginal farmers looking to buy or rent small farm machineries through community sharing dynamics.
- Existing initiatives, such as the Sub-Mission on Agricultural Mechanization (SMAM), would be expanded to incorporate additional hilly region-specific interventions.
- Low-interest loans and financial incentives are offered to stimulate investment in farm gear.

Research and development for hill-specific machinery:

- The creation of small, lightweight, and multi-functional farm machinery designed for hilly terrains.
- Portable post-harvest machineries on underutilized location specific crops of NEH region may develop as innovation priority, viz. buckwheat, perilla, jobstear, millets, etc.
- Introduction of solar and battery-powered farm equipment to minimize reliance on fuel and make automation more cost-effective.
- Collaboration between research institutes, universities, and the corporate sector to develop technologies suitable for modest landholdings.

Expansion of custom hiring centres (CHCs):

- Establishment of more CHCs in all areas to provide mechanized tools, machinery for post harvesting, packaging and values addition. Also providing real-time technical assistance when needed.

Training and skill development programmes:

- Large-scale training programmes to teach farmers about the use, maintenance, and advantages of agricultural machinery and entrepreneurship development.
- Women's and youth capacity-building initiatives to enhance involvement in mechanized agriculture

and entrepreneurship.

- Collaboration with agricultural colleges, KVKs, and ICAR institutions to provide skill-building workshops on mechanization in hilly areas.

Strengthening market links and agro-processing units:

- Cooperative models and farmer producer organizations (FPOs) are being developed to enable communal investment in farm machinery and post-harvest processing units.
- Establishing agro-processing hubs in hill regions to produce value-added goods such as processed spices, dried fruits, and organic food grains.
- Policy actions to improve rural road infrastructure and logistics so that market ready product can reach quickly to the retail outlets with cheaper transportation cost.

SUMMARY

Extensive farm mechanization in hill agriculture remained indispensible to increase the productive capacity and efficiency of hill farming systems in northeast Indian hills. Funding support from public sector institutions on the technical innovations and field scale adaptation of portable lightweight handy machineries for profitable crop cultivation and post harvesting processing became essential to increase crop productivity, farming efficiency and farmers income towards better sustainable daily livelihood of the habitants in northeast India. Community sensitization and participation in capacity building programmes aiming technical expertise development on farm machineries and establishment of farmers' need based custom hiring centres on rental basis, will encourage precision farming across the remote difficult terrains of northeast India in the forthcoming future.

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Articles invited for Special Issues of *Indian Farming* and *Indian Horticulture*

On the occasion of the 98th ICAR Foundation Day

ICAR invites articles for two Special Issues of its flagship magazines, *Indian Farming* and *Indian Horticulture*, to be published on the occasion of the 98th ICAR Foundation Day. Researchers, scientists, and subject matter experts are encouraged to contribute high-quality articles aligned with the themes given below.

1. Special Issue of *Indian Farming* on "Environmental Sustainability"

This issue will focus on innovations, technologies, and products that contribute to Environmental Sustainability and support the attainment of the Sustainable Development Goals (SDGs). Articles should present a clear and complete storyline demonstrating how the described method advances specific SDGs and promotes sustainable agricultural practices.

Authors are requested to follow the submission guidelines available on the *Indian Farming* ePubs portal: https://epubs.icar.org.in/index.php/IndFarm/about/submissions

2. Special Issue of *Indian Horticulture* on "Nutrition and Health"

This issue will highlight advancements that enhance nutrition, improve health outcomes, and promote sustainable food systems, contributing to relevant SDGs. Articles should present a coherent narrative demonstrating how the work supports better nutrition and health through horticultural innovations.

Authors are requested to follow the submission guidelines available on the *Indian Horticulture* ePubs portal: https://epubs.icar.org.in/index.php/IndHort/about/submissions

While submitting the article, please clearly mention that the submission is for the **Special Issue**.

Last date for submission: 28th February 2026