



## Popular Article

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# Hill Farm Mechanization

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### Abstract

This article discusses hill agriculture in India and analyzes terrain-induced constraints influencing mechanization. It outlines information on predominant and emerging crop systems, along with machinery and technologies currently adopted across major hill regions. Key limitations, including soil degradation, limited accessibility, and inadequate equipment suitability, are addressed. The article further provides crop-targeted mechanization options for major hill crops. Overall, it is useful for understanding hill farm mechanization and serves as a basis for several research initiatives.

### Introduction

The potential of hill agriculture has remained under-exploited because of diverse reasons. FAO states that 20% of a Southern Asian land may be steeply sloping hills/mountains, but only about 5% of its population lives there, making such regions less densely populated. Hill areas are found in all the Southern Asian countries, but predominantly occur along the southern slopes of the Himalayan range across India, Bhutan, Nepal, Pakistan and Afghanistan. These hill areas have suffered from extensive deforestation and soil erosion. In Southern India, agroforestry systems in Western Ghats are multi-tiered (trees and crops), supporting both production and ecosystem services. According to Rana *et al.*, (2023), 86% of Uttarakhand state area is mountainous, about 30% of hill farmer households (especially in mid- and high-elevation zones) have left agriculture for non-farm jobs and about 60% of rural hill farming communities are food insecure. According to Jagadesh *et al.*, (2023), Conversion of natural ecosystems to agricultural land negatively affects soil physical properties in Nilgris hills.

Despite these ecological and socio-economic constraints, hill regions sustain a highly diverse agricultural system. These landscapes support both traditional plantation crops and a range of temperate, specialty, and emerging crops. Plantation agriculture dominates many hill regions, with crops such as tea, coffee, pepper, and rubber forming the backbone of

commercial cultivation. Cardamom, a valuable high-income spice crop, is particularly important, often grown under shade trees in agroforestry-based systems that enhance both productivity and ecological stability. Alongside these major plantations, farmers in high-altitude zones also cultivate a diverse range of uncommon and specialty crops. These include temperate fruits such as plums, pears, and peaches, as well as cool-season vegetables like potato, cabbage, and peas that thrive in the mild mountain climate. In addition, exotic and emerging crops like tamarillo, dragon fruit, fig, rambutan, durian, and even certain wild jamun relatives are increasingly being adopted in suitable hill pockets to diversify farm income. Together, this mix of traditional plantations, spice crops, temperate produce, and niche exotics highlights the unique agricultural potential and crop diversity of hilly regions.

With shrinking landholdings, labour shortages, climate stress, and rising food demand, mechanization is no longer just optional or essential, it has become a necessity. The mechanization target was more than 75% in India for the upcoming 2047. To support these operations, a wide range of agricultural machinery is commonly used across India. Land preparation, sowing and planting, intercultural operations, fertilizer application, plant protection, harvesting, post-harvest etc were the farm operations in general, applies to hill farming as well. Commonly used machinery in agriculture can be listed as tractors, power tillers, various tillage implements, seed drills, power sprayers, drones, fertilizer broadcasters, power weeders, reapers, combine harvesters, balers, threshers and post-harvest machinery.

Machinery for hill crops was diverse and also rely on special requirements. To illustrate how these machinery options vary across different hill crops and regions, some representative mechanization practices are summarized in Table 1.

**Table 1. Some of the mechanization aspects in hill crops**

S.No	Crop	Location	Mechanization under practice/progress/research
1.	Terraced paddy	Khonoma Village, Nagaland	Power tiller-based puddling, Compact Walk behind type 4 row rice transplanter, Portable pumps, Walk-behind reapers
2.	Millets	Uttarakhand (Central Himalayan Hills), Himachal Pradesh (Western Himalayas)	Walking tractors, drum seeder, Pedal operated threshers

3.	Tea	Dibrugarh (Assam), Darjeeling (WB), Nilgris (TN)	Plucking machines, Pruning Machine,
4.	Coffee	Nilgris (TN), Chikmagalur (KA)	Power auger, harvesting aids, High-Pressure Knapsack Sprayer, Drone sprayer
5.	Pepper	Idukki (KL), Kollimalai (TN), Yercaud (TN)	Mini tillers, auger diggers, Pepper harvester, harvesting aids like ladder and knife, High-Pressure Knapsack Sprayer, Drone sprayer, pole pruners
6.	Cardamom	Idukki (KL), Theni (TN), Kodagu (KA)	Pod Plucking and Pruning Tools, Drone sprayer, Gravity based ropeway
7.	Carrot	Nilgiris (TN), Kullu (HP), Kalimpong (WB)	Diggers, Harvesters



Fig.1 A Harvesting of Darjeeling Tea (discoveringtea.com), Chikkamagaluru coffee (deccanherald.com), Munnar pepper



Fig.1B Harvesting of Ooty carrot, Tripura rubber (krishijagran.com), Visakapatnam dragon fruit (thehindu.com)

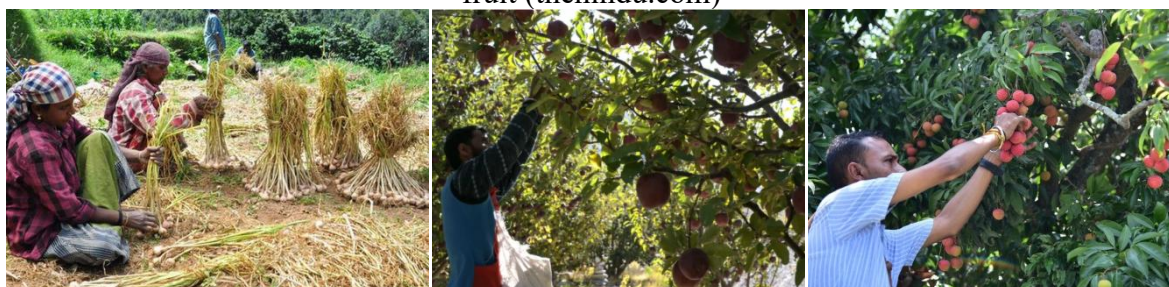


Fig.1C Harvesting of Idukki hill garlic (thehindu.com), Himachal apple (worldbank.org) Assam sweet litchi (english.news.cn)



**Fig 2A. Battery operated tea harvester**

### **Constraints**

The uneven terrain and varying slopes of hill regions make it challenging for standard farm machinery to work safely and efficiently. Large equipment like tractors often face issues with stability and traction on steep gradients, increasing the risk of soil erosion and field damage. Terraced fields designed for erosion control and better water management add another layer of difficulty towards hill farm machinery, demanding careful handling and precise operation. Moreover, the small plot sizes and limited accessibility of hill farms restrict the use of conventional large machines. Consequently, mechanization in hill agriculture typically requires higher investment and solutions that address the unique demands of the terrain. Network availability also found to be lacking in many parts of the hilly terrain (Rathinavel et al., 2023) inhibits the use of latest mechatronics, robotics, IoT etc. Policies and schemes on agricultural mechanization are focused in general like SMAM, which is not exclusive to hill crop mechanization. To address these terrain-related constraints and operational limitations, hill agriculture requires machinery designs and adaptations tailored specifically for sloping and fragmented landscapes.

### **Requirements**

Applying commonly used farm machinery into hill crop is not significantly viable. Hence, the modifications and exclusive designs are needed for solving the purpose. Hill farming needs machinery that are low-weight, compact, easy to maneuver and specialized equipment suited to uneven terrain. Tractors with narrow track width and high torque are ideal for hills, terraced fields and orchards. Wide wheelbase, low centre of gravity and anti-slip features are essential to avoid overturning on slopes. Walk-behind machines are safer than ride-on type machines in steep gradients in safety perspective. Reversible ploughs, adjustable-width blades, and side-shift rotary tillers are better for working close to terrace edges. Contour bund formers, ridge makers, and small seed drills designed for contour sowing help reduce runoff. As a large share of hill farmers are women, women-Friendly tools, lightweight ergonomic tools (wheel hoes, small seeders and mini weeders) are suggested. Ropeways, cable-operated trolleys, mini crawlers are ideal for mobilization of inputs and produces in steep terrains. Network advancements like 5G must be enhanced in hilly regions for the

advanced technology use without hassles. Given the high capital cost of specialized hill machinery and the predominance of small and marginal farmers in these regions, ensuring access through well-equipped custom hiring centres becomes a practical necessity.

### **Custom hiring centres**

Similar to plains, hill farmers also hold small and marginal land holdings. Requirements for mechanized hill farming as discussed above, requires special machinery and equipment. Farmers cannot afford to such machinery, rely on hiring. Also, availability of maintenance facilities in hilly regions is uncertain. Hence, the custom hiring centres at hill station must have suitable machinery with optimal quantities based on crop and season. Strengthening such institutional and service-based mechanisms forms an essential link between field-level machinery needs and broader goals of improving hill agricultural productivity and sustainability.

### **Conclusion**

Hill farming systems are ecologically rich and grow a wide range of crops, but still face many challenges such as steep terrain, soil erosion, small landholdings and limited access to suitable machinery. Experiences from the Himalayan and Western Ghats regions show that compact tools, lightweight machines, and equipment designed for slopes make farm operations safer and easier on terraced fields. Plantation crops, spices, temperate fruits, vegetables, and new exotic crops offer good income opportunities, but farmers can benefit fully only when mechanization issues are properly addressed. Using women-friendly tools, mini power units, drones for spraying, contour-based implements, and low-cost transport systems like gravity ropeways can greatly reduce labour and improve efficiency. Setting up well-equipped custom hiring centres in hill areas is also important to ensure farmers get machines when needed. With such targeted mechanization support, hill agriculture can become more productive, sustainable, and a stronger source of livelihood for local communities.

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