MECHANIZATION CONFRONTS IN SELECTED DISTINCT AGRICULTURAL SYSTEMS

Abstract

Mechanization has significantly advanced various sectors, particularly agriculture, by enhancing productivity, efficiency, and sustainability. This study explores the challenges of mechanization in some distinct agricultural systems. Through survey of literature followed by brainstorming on various agricultural systems, insights were made on the selected unique/complex agricultural systems showing confronts for mechanization. Traditional practices such as the floating paddy system, protected cultivation, pandhal system, hill farming, mixed and intercropping systems, organic farming, and shifting cultivation each present unique hurdles for mechanized solutions. Supportive policies and continued research are essential to developing mechanized solutions for such agricultural practices, thus contributing to sustainable development and improved agricultural productivity through mechanization.

Keywords: *Complex agricultural systems; Mechanization confronts; Sustainable production; Traditional practices*

Introduction

Mechanization has transformed industries as well as agriculture, becoming a cornerstone of modern development. In agriculture, mechanization has drastically increased productivity (Hamilton*et al.*, 2022), efficiency (Vortia*et al.*, 2021), and sustainability (Devkota*et al.*, 2020). By integrating advanced machinery and technologies, farmers can now perform tasks that once took days or weeks in mere hours. Tractors, combine harvesters, and plows have revolutionized soil preparation, planting, and harvesting, reducing the labour needed and minimizing human error. This increased efficiency not only boosts crop yields but also lowers production costs (Peng *et al.*, 2022), contributing to food security and economic stability.

Beyond farming, mechanization drives advancement in manufacturing, construction, and transportation. Automation and robotics in manufacturing streamline production processes, boost precision, and decrease costs. Transportation innovations, such as automated vehicles and advanced logistics systems, optimize the movement of farm goods and inputs, fostering easy mobilityand good connectivity.

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Modern machinery designed to be more energy-efficient and eco-friendly, assisting reductionsin carbon footprints. For instance, precision agriculture tools minimize the use of water and fertilizers, leading to less environmental degradation.

While mechanization has significantly advanced numerous sectors, certain areas still present challenges for its design and implementation. Complex environments and intricate tasks can limit the effectiveness of machinery and automation. Additionally, regions with limited infrastructure or access to technology face hurdles in adopting advanced machinery, which can exacerbate disparities between developed and developing areas. Addressing these difficulties requires innovative solutions and ongoing research to develop adaptable, versatile technologies that can overcome the unique challenges of these areas. Hence this study this study was undertaken to discuss the unique/complex environments exhibiting confronts on mechanization through collection of literature survey, brainstorming and drawing the insights.

Methodology

The study was conducted with three different phases as follows, literature survey, brainstorming for classification and drawing insights. Various literature on mechanization keywords was surveyed through Google Scholar, Research Gate and Springer. More than 100 research/review/popular/magazine articles in English language within India were referred. Different agricultural systems were identified across India from the literature survey. Wetland system, orchard system, dryland system, floating paddy system, rotational system, intercropping or mixed cropping system, hill agriculture, protected cultivation system, shifting cultivation system, silviculture system, forestry system etc were identified for mechanization aspects and brainstorming performed with a panel of 15 experts in the field farm mechanization. Systems were identified with following difficulty criteria – Crop speciality, crop morphology, climatic conditions, geographic difficulty, cultivation practices, nature of inputs, suitability with regular/existing machinery. Each criterion was ranked with 10 grade points on difficulty and 0 for ease or mechanized and inbetween for intermediary stages. Top score skewed systems were identified and insights were drawn on the found systems for mechanization difficulties.

Result and Discussion

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- The most of important thing is to mention the locations where the study was conducted. This reason is to show the importance of study in finding out the potential and challenges of mechanization in those regions.

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The various agricultural systems were prevalent in India including rainfed agriculture, irrigated agriculture, dryland agriculture, mixed cropping, agroforestry, pandhal system, hill farming, organic farming, pastoralism, urban agriculture, wetland agriculture, water-logged paddy farming, protected cultivation system were found. In these, complex agricultural systems shortlisted are water-logged paddy system, protected cultivation system, pandhal system, hill farming system, mixed and intercropping systems, shifting cultivation system, organic farming system. Each selected system was discussed as follows.

Water-logged paddy system

According to ICAR, in India, about 3.0 million ha paddy field is affected by water logging, especially in the coastal region.But some parts of country is exclusively cultivating the paddy under water logged conditions naturally. The water-logged paddy system (Lim*et al.,* 2022) was predominantly practiced in Kerala including Pokkali (Rathinavel *et al.,* 2022), Kole (Chandran *et al.,* 2021), Kaipad (Purandhar *et al.,*2022)lands which have unique saline water logging characteristics. Characterization and classification of natural and altered hydromorphic saline soils (Kaipad soils) of North Kerala and West Bengal, is characterized by the cultivation of rice in waterlogged, marshy beds. This traditional method, known for its adaptation to flood-prone regions and/or salinity, involves cultivating rice on a natural water stagnated condition or manually created fields with water using back waters controlled through sluice gates. Mechanization in this system faces notable challenges due to the unique environmental conditions. The waterlogged, marshy, unstable nature of these fields makes it difficult for conventional agricultural machinery to operate effectively. Tractors and harvesters, designed for stable, dry land, struggle with the floating, which cannot enter the fields. Bunds formed for stagnating the water within the field are also a major constraint for movement of machinery in between the fields. Consequently, while mechanization has revolutionized many agricultural practices, its application in water-logged paddy systems requires tailored solutions to address these specific challenges.

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Fig.1 Waterlogged paddy cultivation in Kerala

Protected cultivation system

Protected cultivation in India is mere grown to 2.0 lakh ha (Singh, 2023). Protected cultivation systems, such as greenhouses and shade houses, offer a controlled environment for growing crops, shielding them from adverse weather and pests. However, mechanizing these systems presents several challenges. The confined and often complex layout of protected structures can restrict the movement and operation of larger machinery, making it difficult to deploy equipment for tasks such as planting, watering, and harvesting. Additionally, the delicate nature of the crops grown in these systems necessitates precision and care, which can be challenging to achieve with automated machinery. Customizing equipment to fit the specific dimensions and requirements of different protected cultivation setups can be both costly and technically demanding. Furthermore, ensuring that mechanized solutions are adaptable to the varying microclimates within these structures adds another layer of complexity. As a result, while mechanization holds promise for enhancing efficiency in protected cultivation, overcoming these obstacles requires innovative design and tailored solutions.

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Fig.2 Poly House Capsicum Field

Pandhal system

The Pandhal system, traditionally used in regions like Kerala for growing vegetables such as bitter gourds, involves cultivating crops on raised, slatted platforms supported by a framework of bamboo or wood. This method provides several benefits, including improved drainage, reduced pest damage, and easier harvesting. However, mechanizing this system poses significant challenges. The intricate and often irregular structure of Pandhal setups makes it difficult for conventional machinery to navigate and perform tasks like planting, tending, or harvesting efficiently. Additionally, the manual labor involved in constructing and maintaining these platforms does not easily lend itself to automation. The variability in platform design and size across different farms further complicates the development of standardized mechanized solutions. Consequently, while the Pandhal system offers unique advantages for vegetable cultivation, its adaptation to mechanized farming requires innovative approaches to address these specific challenges.

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Fig.3 Pandhal System for bitter guard

Hill farming

Potential of hill agriculture has remained under-exploited due to various reasons (Bharadwaj*et al.*, 2024). Hill agriculture, characterized by farming on steep, uneven terrains, presents significant challenges for mechanization (Vatsa, & Singh, 2021). The rugged landscape and variable slopes make it difficult for conventional machinery to operate efficiently and safely. Tractors and other large equipment may struggle with stability (Yan *et al.*, 2024) and traction on inclines, leading to potential soil erosion and damage. The intricate layout of terraced fields, often designed to prevent erosion and maximize water retention, further complicates mechanized farming, as these systems require careful maneuvering and precise operation. Additionally, the limited size and accessibility of hill farms can restrict the use of larger machines, necessitating specialized, smaller-scale equipment that can handle the unique demands of this environment. As a result, mechanization in hill agriculture often involves higher costs and complex solutions tailored to the specific challenges of the terrain.

Fig.4 Hill farming practices

Mixed and intercropping systems

Mixed and intercropping systems, where multiple crops are grown together in the same field, pose significant challenges for mechanization. These systems often involve diverse plant species with varying growth patterns, heights, and harvest times, making it difficult for machinery to efficiently handle multiple tasks simultaneously. The irregular spacing and differing growth stages of the crops can complicate tasks such as planting, weeding, and harvesting. Additionally, the presence of multiple crops can lead to increased wear and tear on machinery, as well as the need for specialized equipment to avoid damaging certain plants. These complexities make it challenging to design and implement mechanized solutions that are both effective and adaptable to the varied needs of mixed and intercropping systems.

Fig.5Intercropping in Coconut

Organic Farming

In India, according to certification from National Programme for Organic Production and Participatory Guarantee System, India had 59.12 lakhha of land covered with organic farming (as of July 2022).In organic farming, mechanization faces several challenges due to the fundamental principles and practices that distinguish it from conventional agriculture. Organic farming emphasizes minimal use of synthetic chemicals and artificial inputs, focusing instead on organic inputssuch as composts, manures like panchakavya (Bajaj*et al.*, 2022), litters, biofertilizers (Suchithra*et al.*, 2022), meal (Gowthaman*et al.*, 2021)etc., and sustainable practices. This approach often involves diverse crop rotations (Das*et al.*, 2020), varied planting systems (Montgomery*et al.*, 2021), and the use of organic fertilizers and pest control methods (Costa*et al.*, 2023), which can complicate the integration of standardized machinery. Mechanized solutions must be highly adaptable to handle a wide range of tasks, from precise weeding without disturbing soil health to managing different crop types and growth stages. Developing machinery that aligns with organic principles while maintaining high productivity and sustainability remains a significant challenge.

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Shifting cultivation

Shifting cultivation (Sharma*et al.*, 2023), like Jhum, prevalent in north eastern India (Das *et al.*, 2021) poses unique challenges for mechanization due to its inherent practice of rotating fields and using cleared forest land, which complicates the consistent application of machinery. The traditional method involves manual clearing and cultivation of land, followed by a period of fallow to restore soil fertility. Mechanization in shifting cultivation faces difficulties because the frequent movement of farming areas and the often steep, uneven terrain make it challenging to deploy and maintain large, mechanized equipment. Additionally, the labor-intensive nature of shifting cultivation, which includes tasks like manual weeding and planting, does not easily translate to mechanized processes. Developing adaptable machinery that can handle diverse and shifting landscapes while aligning with traditional practices remains a significant hurdle in modernizing this agricultural system. Also, Bharadwaj*et al.* (2024) stated that shifting cultivation causes deforestation and further climate change.

Conclusion

Research and development must focus on creating adaptable machinery that can handle the specific conditions of each unique and complex system of agriculture while maintaining efficiency and sustainability. Bridging the mechanization gap in these traditional practices is crucial for enhancing food security, as improved mechanization can lead to higher yields and reduced production costs. Support for mechanizing these systems involves not only technological advancements but also policy measures and investment in infrastructure to facilitate the adoption of modern equipment.

Comment [LH21]: The conclusion should start a summary of the main points presented in the results. Then, the conclusion should be more specific, referring to the study. Therefore, please rewrite it clearly and concisely.

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