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A study on the impact of agricultural mechanization and practices of traditional knowledge in agriculture in jhenaidah district, Bangladesh

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Abstract This study investigates the impact of agricultural mechanization and traditional agricultural knowledge on the agrarian community in a village situated in Jhenaidah District, utilizing Eric Wolf's peasant ecotypes theory and the Cultural Lag Theory developed by William F. Ogburn. The research adopts a qualitative methodology, combining primary data from fieldwork and enthnographic interviews along with secondary data from literature reviews. The theoretical framework in shaped by paleotechnic ecotypes, characterized by traditional labor-intensive practices, and neotechnic ecotypes, marked by modern, technology-driven systems. The findings indicate that farmers are struggling to fully adopt and effectively utilize modern agricultural technologies, remaining partially tethered to traditional farming practices. This dichotomy has created a state of cultural conflict, hindering agricultural development. Moreover, findings reveal a significant shift from traditional to modern agricultural practices over the years, driven by governmental policies and market forces. While mechanization has increased productivity and efficiency, it has also escalated production costs and introduced market dependencies. Furthermore, mechanization has altered labor dynamics, reducing the reliance on human labor, particularly marginalizing women's traditional roles. Despite these changes, farmers continue to integrate traditional knowledge into modern practices, demonstrating resilience and adaptability. This study investigates a subtle understanding of the cultural transformations in rural agriculture, providing insights for future rural development strategies.

Keywords: agricultural mechanization, paleotechnic, neotechnic, ecotypes, cultural lag, cultural conflict

1. Introduction

This present study focuses on the relationship between modern agricultural technology and traditional agricultural knowledge in Jhenaidah District, Bangladesh. The district, located in the southwestern region, is a good example of agricultural transformation in an agrarian setting. As a predominantly agrarian nation, Bangladesh has witnessed significant transformations in its agricultural practices over the years, driven by the introduction of mechanized farming techniques and technological advancements (Mrema et al., 2008). This transition has reshaped production methods and deeply impacted the social, economic, and cultural dimensions of rural communities. Scholars have long recognized that Technological development is widely acknowledged as a complex process, shaped by cultural, social, and psychological factors (Foster, 1962). Anthropological studies on transformations in peasant societies have highlighted the diversity of human responses to technological change across various cultural contexts. As part of this transformative process, emphasizes the importance of agricultural modernization to enhance productivity (Chowhan, 2020). Agricultural mechanization embodies this shift, introducing non-human sources of power to streamline agricultural operations and increase efficiency. The Green Revolution had a significant impact on agriculture practices in Bangladesh, as it did in other parts of the world (Sala and Bocchi, 2014). Before the decade of the 1990s, economists and policymaker's predictions were that mechanization would have displaced labor and ultimately led to unemployment in rural areas, which would disrupt the social system (Islam, 2016). Scholars such as Ahmed (1965) and Alim (1974) initially argued that mechanization would be impractical in regions characterized by small, fragmented land holdings. However, these views have evolved with advancements in agricultural technology. Agricultural machinery has demonstrated significant profitability, with investment costs often recovered within two to three years (Hossen, 2019). Research highlights both the benefits and drawbacks of mechanization, noting increased operational efficiency, profitability, reduced labor demands, decreased postharvest losses, and improved grain quality. The adoption of mechanization reduces turnaround times between crops, alleviates labor shortages during peak seasons, and generates additional employment opportunities in rural areas (Islam et al., 2018). Mechanization also promotes off-season employment in non-farm sectors, especially benefiting women farmers. Islam argues that mechanization mitigates labor shortages and contributes to poverty reduction and livelihood enhancement for the rural poor. Miah et al., (2002), analyzed that farm mechanization

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positively impacted agro-based and allied industries, creating employment opportunities for rural laborers and improving their standard of living. It also led to significant increases in annual income, household expenditure, savings, and household asset position. While reviewing scholarly and gray literature, most of the studies discussed the impact of farm mechanization, technology adoption, socio-economic impact, environmental impact, challenges, advantages and disadvantages of farm mechanization.

Very few attempts have so far been made to analyze the complex relationship between modern agricultural technology and practices of local agricultural knowledge. But it is important to study how agriculture technology has changed and its impact on their farming systems and practical knowledge. The agrarian community is experiencing a transformative process, with shifting boundaries and evolving perspectives. The introduction of modern agricultural machinery has significantly influenced local farming practices, altering traditional methods developed through generational knowledge. Apart from this, the use of modern agricultural machinery has also influenced the local knowledge that farmers used to conduct agricultural work using their own knowledge. In addition, farmers have been inventors by nature since ancient times. Although they do not know the theoretical formula, they invent new methods and processes through intensive thinking. An illustrative example is the case of Haripad Kapali, a self-taught rice variety inventor who revolutionized local agriculture by inventing 'Haridhan' without prior knowledge or formal education. While numerous studies have explored the adoption of agricultural technology and mechanization, there remains a dearth of research specifically addressing the intricate interplay between modern technology and traditional knowledge within the agricultural landscape. In the above-mentioned statement, it is clear that this issue is still absent. It encouraged us to select the research topic. The major research objectives of this study are to explore the impact of modern agricultural technology on agriculture, including local agricultural practices and cultural heritage. The objectives of this study are following:

a. To examine the adoption of farm machinery and analyze its impact on traditional farming practices.
b. To explore how farmers integrate or resist farm mechanization based on their traditional practices.
c. To examine the present traditional farming practices in the study area.

2. Materials and Methods

A qualitative research method has been used in the present study, a method particularly essential for understanding the complex societal dynamics, cultural difference, and human behaviors within agrarian settings (Bernard, 2017). In addition, this study employed both primary and secondary sources of data to explore the impacts of agricultural mechanization on traditional knowledge practices within the agrarian community of Dudhshar village in Shailkupa Upazila, Jhenaidah District, Bangladesh. Dudhshar village was chosen for its reliance on agriculture and its significant engagement with both mechanized technologies and traditional farming methods. The study aimed to understand how mechanization affects traditional practices, informed by the theoretical frameworks of Eric Wolf's peasant ecotypes and William Ogburn's Cultural Lag Theory, which provide insights into the interaction between material advancements and cultural adaptation in agricultural contexts (Bernard, 2017; Ogburn, 1922). Data was gathered from two sources: primary and secondary. Primary data was collected directly from the study population in the research area, predominantly based on fieldwork, utilizing in-depth interviews, focus group discussions (FGDs), case study, and participant observation. Secondary data was gathered from various sources, such as books, articles, journals, and newspapers. To identify suitable participants, a preliminary survey was conducted with 60 farming households. The pilot study examined land ownership, resource access, and the use of agricultural tools, helping to refine the study's data collection methods. Based on the pilot findings, 30 families were selected for in-depth interviews using convenience sampling, ensuring a representative sample of participants who engage in both mechanized and traditional farming. In-depth interviews were conducted with 30 farmers, chosen based on their extensive farming experience. Each participant had a minimum of 5 years in agriculture, which allowed the study to draw on well-established farming knowledge, both mechanized and traditional. The purpose of In-depth interviewing is to explore farmer's personal narratives and experience of modern agricultural technologies. In-depth interviews are especially beneficially when motivated to explore complex topics and "thick descriptions" that structured surveys may not address (Spradley, 1979; Granot et al., 2012). A narrative and storytelling approach was applied while conducting ethnographic interviews. To enhance data collection, three key informants were chosen, and efforts were made to involve the broader community. Additionally, five case studies were undertaken to delve into specific challenges faced by individual farmers, while three focus group discussions (FGD) were organized to gather collective perspectives on key issues.Focus Group Discussions (FGDs) technique facilitated a collective understanding of mechanization's impacts within the community. Three FGDs were conducted, each involving 8–10 participants, to discuss issues such as mechanization's influence on labor dynamics, knowledge preservation, and cultural adaptation. FGDs are particularly effective in community-based research, as they capture social interactions and reveal shared values and concerns within groups (Morgan, 1997). Moreover, Participant observation complemented the interviews and FGDs by allowing the researcher to engage directly with agricultural activities. Observational methods are essential in ethnographic research, as they enable researchers to understand implicit social norms and practices that may not emerge in interviews (Bernard, 2017). Through observation, we gained insights into how traditional and mechanized practices coexist and impact

labor and resource management within the community. Thematic analysis was applied to analyze the data, focusing on themes such as cultural adaptation, economic implications of mechanization, and knowledge preservation. Initial coding was conducted manually to organize narratives related to the study's key themes, following best practices for qualitative data analysis (Saldana, 2016). Triangulation was employed to cross-validate findings from interviews, FGDs, and observational data, enhancing the credibility and reliability of the research results (DeWalt & DeWalt, 2011). We adhered to ethical guidelines to ensure respect for participant autonomy and privacy. Participants were fully informed of the study's purpose, and written consent was obtained prior to data collection. Confidentiality was maintained by anonymizing participants' identities through the use of pseudonyms, and all data were handled in compliance with ethical research standards, as recommended by the American Anthropological Association (American Anthropological Association, 2012).

2.1. Conceptual and theoretical framework

Agriculture is the science and art of raising plants and animals, encompassing various activities such as crop farming, the cultivation of fruits, vegetables, flowers, or decorative plants, and the breeding and rearing of animals (Singh, 2024). However, for the purposes of this study, the term agriculture will be used exclusively to refer to agricultural cultivation. A farmer is defined as a person who engages in agriculture and rears live creatures for food or raw materials. Farmers can specialize in various areas, including crop farming, fish farming, dairy production, and poultry farming. However, within the context of this research, the term farmers will specifically refer to those who are involved in crop farming. Other types of farmers, such as those involved in fish, dairy, or poultry farming, are not included in this study. Agricultural mechanization, on the other hand, refers to the process of replacing human labor across the entire agricultural value chain with alternative energy sources, such as animal power, fossil fuels, or renewable energy (Rahman et al., 2021). For the purposes of our study, agricultural mechanization is defined as the substitution of human labor with other energy sources throughout the agricultural value chain. This transition includes the implementation of advanced machinery equipped with features such as Power Tillers, irrigation Pump, Tractor, Fertilizer and specialized harvesting tools. On the other hand, Traditional Knowledge (Indigenous Knowledge) refers to the practical knowledge held by native populations within specific ethno-cultural and ethno-agricultural settings. This knowledge is tangible, dynamic, and relies on intuition, perceptible data, and accumulated past experiences (Merillon & Ramawat, 2012). In this study, traditional knowledge specifically refers to the knowledge and practices of farmers in their cultivation activities.

This proposed study is designed to analyze the impact of agricultural mechanization and the range of traditional knowledge within the agrarian community. For the present study, we have adopted the Peasant Ecotypes Theory developed by pioneering anthropologist Eric Wolf (1966) and the Cultural Lag Theory developed by sociologist William F. Ogburn (1922). In our research, we utilize Eric Wolf's concept of peasant ecotypes to analyze agricultural practices. He describes two distinct ecotypes: the paleotechnic and the neotechnic. His classification of peasant ecotypes offers a valuable framework for understanding the transformation of agricultural practices and their indigenous knowladge implications. "Paleotechnic Ecotypes" represent traditional, labor-intensive agricultural systems characterized by reliance on human and animal labor with minimal use of advanced machinery. These systems are marked by sustainable practices utilizing techniques passed down through generations, emphasizing environmental harmony. Agricultural knowledge is deeply embedded in the local cultural and social fabric, with practices tailored to local conditions. The primary focus of paleotechnic ecotypes is on meeting the needs of the local community, operating within a subsistence economy with little surplus for trade. In contrast, "Neotechnic Ecotypes" represent modern, technology-driven agricultural systems characterized by extensive use of advanced machinery and technology to increase productivity. These systems emphasize efficiency and economic returns, often employing intensive farming practices. The application of standardized techniques based on scientific research leads to uniformity in agricultural practices. Neotechnic ecotypes are geared towards market-oriented production, focusing on generating surplus for trade and export.

Additionally, we apply William F. Ogburn's (1922) Cultural Lag Theory to understand the disparity between technological advancements and the slower pace of cultural adaptation. According to Ogburn (1922), cultural lag occurs when material culture (e.g., technology, machinery) changes rapidly, while non-material culture (e.g., values, beliefs, social norms) takes longer to adjust. This lag can lead to social problems and disorientation as communities struggle to integrate new technologies within their traditional frameworks. By integrating the theoretical lenses of paleotechnic and neotechnic ecotypes and cultural lag, this research provides a nuanced understanding of the complex interplay between traditional knowledge and modern agricultural practices in Jhenaidah District.

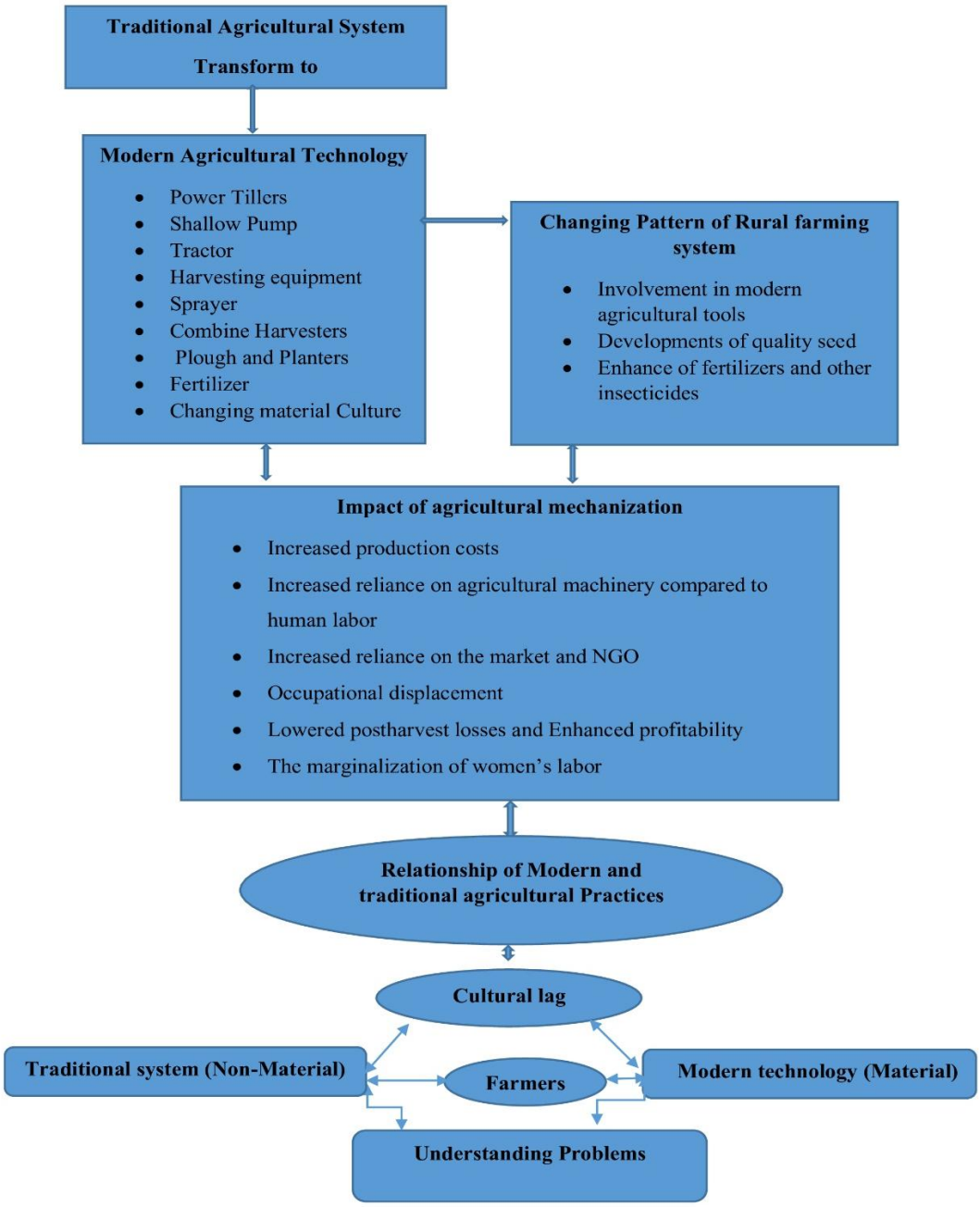

Figure 1 Conceptual framework for the change and transformation of agricultural mechanization from traditional to modern.

3. Results

3.1. The transition from traditional to modern agricultural practices: An overview

Over the years, Bangladesh has witnessed a significant evolution in its agricultural development policies, driven by both governmental initiatives and market liberalization. Agricultural mechanization in Bangladesh began in the 1950s, spurred by government-led schemes such as the 'Mechanized Cultivation and Power Pump Irrigation' program, which introduced tractors and irrigation engines to farmers, setting the stage for a gradual transition from traditional farming methods to mechanized agriculture (Mrema et al., 2008). During the 1960s, distribution of machinery like pumps, tractors, and sprayers was supported by workshops to produce and maintain this equipment (Mottaleb et al., 2016).

After liberation war, the government conducted a comprehensive survey to revitalize the agricultural sector, launching a master plan aimed at addressing issues like land fragmentation. This initiative emphasized the establishment of integrated farms and support systems, including the provision of quality seeds, fertilizers, insecticides, and irrigation facilities, encouraging farmers to expand crop production. The Government of Bangladesh (GOB) established various organizations like the Bangladesh Agriculture Research Council, Bangladesh Agriculture Development Corporation, Uddayan Development Board,

Cotton Development Board, Seed Certification Agency, etc. (Sarker, 2020; Rahman and Ghose, 2019). In Late 1970s, the Government of Bangladesh (GOB) continued to support agricultural mechanization by establishing large-scale irrigation facilities through deep tube wells (DTWs) and renting out low lift pumps (LLPs), which were subsidized through the BADC. However, due to financial and administrative challenges, a shift towards privatization occurred in the 1980s, allowing market liberalization policies to take effect. This shift led to increased private ownership of machinery by farmer cooperatives and individuals, marking a significant departure from the state-led initiatives of previous decades (Clarke , 1997; Hossain, 2009). By the 1990s, market liberalization had further accelerated mechanized farming, significantly increasing the use of power tillers and irrigation units throughout the country, including in Dudhsar village. This village agricultural framework, like much of rural Bangladesh, has been heavily influenced by modern machinery and projects such as the Ganges-Kobadak (GK) Irrigation Project. These irrigation facilities spurred interest in high-yielding variety (HYV) seeds, initially distributed free to farmers by government officials to encourage paddy cultivation. While the project promoted productivity, it also revealed limitations particularly in higher land areas that could not be adequately irrigated prompting farmers to invest further in modern technologies like and tillers. However, the high cost of such machinery restricted its adoption primarily to wealthier farmers, creating socio-economic divides within the village. We observe a dual pattern: wealthier farmers in this village, aligned with neotechnic ecotypes, were early adopters of mechanization, driven by market-oriented practices and profit goals. These farmers utilized bank loans to purchase power pumps and tillers, using them to increase their productivity and income by leasing equipment to other farmers. For example, in 1982, a farmer named Moslem Mandal acquired the first power pump in the village through a bank loan, inspiring others to follow suit. This shift from traditional farming to mechanized practices reflects a transition towards neotechnic methods prioritizing efficiency and productivity (Wolf, 1966). In contrast, farmers who could not afford mechanization maintained traditional farming methods, reflecting paleotechnic ecotypes focused on self-sufficiency and minimal reliance on external inputs. This division underscores Ogburn's Cultural Lag Theory, where the rapid advancement of material culture namely mechanized farming has outpaced the social adaptation of less affluent farmers. This lag manifests in socio-economic stratification, as access to technology remains uneven, highlighting the challenges of adapting to modern agricultural changes. Non-governmental organizations (NGOs) like Grameen Bank, BRAC, and Asha also played a pivotal role in advancing mechanization from the 1990s onwards, offering loans that facilitated machinery acquisition. However, the impact of these loans varied: while some farmers used funds effectively, others struggled with loan repayments after using the money for non-agricultural purposes, highlighting the financial risk involved in mechanization. From 2005 onwards, the region saw a notable increase in modern agricultural technology, fueled in part by profits from tobacco and vegetable cultivation. Our ethnographic data indicate that, over the past five years, farmers in our study area have extensively adopted advanced machinery like tractors, rice transplants, reapers, bed planters, and combined harvesters. One respondents, Zafar Sheikh (65), shared his experience:

'' I started farming father at the age of 13 or 14, Zafar recalls that previously, a single crop was cultivated due to inconsistent water availability. In agricultural technology and irrigation have now enabled year-round cultivation, improving both ease and efficiency Machines save labor and improve crop quality, transforming farming here" (IDI).

The agricultural system of Dudhsar village is now undergoing change, moving away from traditional farming methods and toward more technology based and advanced ones. Actually, this narrative illustrates the ongoing shift in Dudhsar village from traditional farming to mechanized agriculture, where Wolf's neotechnic ecotype represents those adapting to technological advances. Meanwhile, Ogburn's Cultural Lag Theory explains the resistance to mechanization among those still rooted in traditional practices, underscoring the discord between technological progress and cultural adaptation. This transformation reflects both the benefits and challenges of integrating modern agricultural methods in rural settings, as Dudhsar's farming community navigates the complexities of evolving agricultural practices.

3.2. Effects of modern machineries

3.2.1. Increased production costs

Before the advent of modern agricultural machinery, farming in Dudhsar village relied on a low-cost, self-sufficient model. Families provided nearly all inputs, including seeds, labor, and organic fertilizers, with cattle as the primary means of cultivation. Household labor and rain-fed irrigation systems supported traditional farming methods, keeping production costs minimal. In this setting, farmers reflected paleotechnic ecotypes, where subsistence and sustainability took precedence over market-oriented practices (Wolf, 1966). In contemporary agricultural practice, farmers are heavily reliant on market systems for their production needs. Agricultural inputs such as seeds, fertilizers, pesticides, machinery, and irrigation now necessitate the use of diesel and other purchased resources. This shift towards modern agricultural technologies has significantly altered the economic point of view of the farmers. Today, traditional inputs sourced locally have largely been replaced by alternatives. For instance, domestically saved seeds have given way to high-yield seeds purchased from commercial sources, cow-drawn plows are increasingly supplanted by power tillers, and organic fertilizers are substituted with chemical options. As modern agricultural methods became prevalent, household labor decreased in importance, replaced by hired labor and pump-based

irrigation systems. While these advancements have increased productivity, they have also driven up the cost of farming, creating an economic burden on farmers. In context, Jumrat Ali (70), reflects on these economic challenges:

"When we started farming, there was no money to pay for the work. We would have eaten once. But now the price of a worker is 400 tk. During the season, there's a shortage of workers, and the rate goes up to 500 tk. Along with this, fertilizers, diesel, seeds are now all bought in the market. Every year, prices go up, but our crop prices don't. Now I hesitate to spend money on farming. Farming has become very expensive" (KII).

Another respondent Hukumat Joardar, a 65-year-old farmer, began farming at the age of 12 and initially relied solely on cow dung manure. Post-independence, the introduction of urea and irrigation pumps shifted his farming practices towards high-cost inputs like phosphates, potash, and other chemical fertilizers. This diversification in inputs has driven up cultivation costs, transforming both the methods and economics of farming in Dudhsar village. These experiences illustrate as farmers struggle to reconcile traditional low-cost, self-sufficient methods with the higher costs of mechanized farming. The material aspect modern machinery and market-dependent inputs has evolved rapidly, whereas the non-material cultural adaptations needed to manage these financial burdens have lagged (Ogburn, 1922). This disparity creates economic strain for farmers who must now navigate market fluctuations, escalating input costs, and a growing dependence on purchased resources, which stands in stark contrast to their historically self-sufficient practices. Thus, the transition in Dudhsar village from paleotechnic to neotechnic ecotypes highlights both the economic gains and the cultural and financial challenges mechanization imposes. While modern machinery and high-yield farming techniques have boosted productivity, they have also increased production costs multiple times over, reshaping the economic perspective of agricultural production and imposing new financial burdens on farmers.

3.2.2. Dependence on modern machinery over human labor

Data reveal that traditional, nature-based farming practices persisted in study area until the early 1980s, with farmers relying on cow-drawn plows, ladders, and rainwater for cultivation. However, the introduction of irrigation pumps and power trailers marked a substantial departure from these methods. According to the household census, most of the farmers now use irrigation system and modern agricultural machinery for tasks such as paddy threshing, spraying, and land preparation. In this regard, Muntasir Rahman (63) shared that,

His paternal grandfather would work from morning to evening using only a cow plow. Today, tasks are accomplished much faster with power tractors, and his family has expanded their irrigation to include three pumps, replacing their previous reliance on canal drainage. Similarly, labor-intensive practices like manually carrying crops have been replaced by vans, while vegetable spraying is now mechanized (FGD Participant). .

These changes indicate a significant shift toward reliance on agricultural machinery, prioritizing efficiency and production over traditional, labor-intensive methods. Traditionally, family members served as the primary labor force, reflecting Wolf's paleotechnic ecotypes, where subsistence-based practices were grounded in collective labor and within extended family structures. However, the adoption of machinery has shifted farming in here toward neotechnic ecotypes that emphasize mechanized efficiency, replacing family labor with technology-driven practices (Wolf, 1966). This shift is evident in the experiences of respondents like Joad Mandal (75), who recalls that.

''*when he was young, agricultural tasks were community efforts supported by large family networks. Boys joined farming from a young age, learning alongside older family members as they balanced schooling with agricultural responsibilities. Hired labor was minimal, and when used, workers were often compensated with food rather than wages. However, as joint family structures declined and smaller family units became the norm, the ability to rely on family labor diminished, prompting an increased reliance on machinery"(IDI).*

This data highlights a significant shift in agricultural practices in Dudhsar village over the past 40-50 years. The once family labor-dependent farming system has transitioned to a more modern approach, heavily reliant on machinery. Cultural Lag Theory helps explain this transformation: while material culture (agricultural machinery) has advanced, the non-material cultural aspects (family labor systems and community-based practices) have adapted more slowly, creating a cultural gap (Ogburn, 1922). This lag has impacted study area's social structure, as machinery has replaced communal labor, altering relationships and reducing the community's reliance on traditional knowledge-based practices. This transition is linked not only to technological advances but also to changes in family structures, as the shift from joint to nuclear families has reduced available labor, further necessitating mechanized solutions. Consequently, while machinery has improved farming efficiency, it has also contributed to the erosion of traditional, knowledge-based practices, transforming the socio-cultural fabric of agricultural life in Dudhsar village.

3.2.3. Increased reliance on the market and NGOs

Agricultural practices in Dudhsar village have experienced a profound shift due to modern technology and market integration. Farmers increasingly acquire high-yielding seeds from the market or agricultural offices, moving away from the traditional practice of saving seeds for future planting. While some farmers continue to collect seeds independently, the majority now rely on market sources. This dependency extends to other agricultural inputs, such as chemical fertilizers, pesticides, diesel, and machinery, which must also be purchased from the market. One respondents Zulfikar Ali (52) reflected on this transformation,

''He explained that all agricultural materials are now bought from the market, and when financial constraints arise, loans from NGOs are utilized. The availability of loans has been beneficial, allowing for gradual repayment and the possibility of securing additional loans in the future.“

The statement clearly show that the agriculture of Dudhsar village has evolved from a self-sufficient, family-based system to a market-dependent, technologically advanced one. This traditional approach aligns with Wolf's paleotechnic ecotype, where agricultural practices were largely self-sufficient and based on locally sourced inputs (Wolf, 1966). However, the introduction of high-yielding seeds and modern agricultural materials has diminished this self-sufficiency, as farmers now purchase nearly everything required for cultivation from the market. This transition to market dependency aligns with the characteristics of Wolf's neotechnic ecotype, which prioritizes productivity through external inputs and advanced technology (Wolf, 1966). The shift began with the introduction of mechanized irrigation, chemical fertilizers, pesticides, and high-yield seeds, gradually replacing the family-focused agricultural model. Although modern machinery and chemical fertilizers have boosted production; however, they have also raised production costs, as previously analyzed. Consequently, many farmers now depend on NGOs to cover these additional expenses. The increased production costs associated with modern farming practices have also led many farmers to rely on NGOs for financial support. Loans from organizations like BRAC and Grameen Bank have become essential for covering agricultural expenses, as Aynal Joadder (45) explained:

“All agricultural materials are now bought from the market, and when financial constraints arise, loans from NGOs are utilized. The availability of loans has been beneficial, allowing for gradual repayment and the possibility of securing additional loans in the future” (IDI).

Ogburn's Cultural Lag Theory provides insight into the social adaptation challenges arising from this dependency on market systems and loans. The material aspect (modern agricultural inputs and financial mechanisms) has advanced more rapidly than the non-material cultural practices of self-sufficiency and community-based resource sharing. This cultural lag has created new vulnerabilities, as farmers face financial risks tied to crop prices, market fluctuations, and loan repayment schedules, which were previously absent in traditional farming systems (Ogburn, 1922). This shift from a family-based, self-reliant system to a market-dependent, technologically advanced agricultural model illustrates both the benefits and risks of modernization. While productivity and social networks have expanded, these gains come at the cost of financial independence and introduce a reliance on external funding and market stability. The role of NGOs in providing credit has become crucial, but the reliance on borrowed funds underscores the need for sustainable financial practices that align with the community's evolving agricultural needs.

3.2.4. Occupational displacement

Before the mechanization of agriculture, human labor played a crucial role from sowing seeds to harvesting crops. However, the advent of mechanized farming systems has significantly reduced the need for human labor in agriculture. Modern agricultural technology now performs most of the agricultural tasks, marginalizing the role of human laborers. Consequently, many laborers who once relied on agricultural work for their livelihood are compelled to seek alternative professions. Our findings indicate that mechanization has significantly transformed the occupational landscape in Dudhsar village. Common non-agricultural jobs now include driving machinery, rickshaws, or buses, and working as construction laborers. This shift is exemplified by one respondent Rabiul Islam (45), who has worked as a day laborer since he was 15 years old.

As a day laborer with six family members, he has worked on others' lands since he was 15. He recalls that five years ago, there was abundant work, but now, even on full moons, he and other laborers often find themselves idle. He observes, "The work that can be done now with a machine in 1 hour used to take ten laborers all day." Consequently, Rabiul has shifted to working as a mason (FGD Participant).

This statement illustrates how mechanized farming has increased dependency on machinery over human labor, reducing its influence on agriculture. Many poor residents of Dudhsar village, whose ancestors were farmers, now engage in various jobs. While modern agricultural machinery allows for different employment opportunities, it also exacerbates their struggles. Unlike the past, when laborers received food and grain as part of their wages, they now rely solely on cash payments. This transition reflects the movement from a paleotechnic ecotype where labor-intensive, community-based agriculture was prevalent to a neotechnic ecotype that emphasizes mechanized efficiency over human labor (Wolf, 1966). Mechanization has shifted the dependency within agriculture, marginalizing traditional labor roles and reducing the influence of manual labor in

farming. Many of poorer farmers in this village, who come from generations of farming families, have adapted to non-agricultural work. Although modern machinery has opened new employment opportunities, it has also intensified financial struggles by removing the security of traditional patron-client relationships. Cultural Lag Theory provides insight into the effects of mechanization on laborers in study area. The material culture (machines that increase efficiency and reduce labor needs) has evolved rapidly, while the non-material cultural elements such as secure employment, community support, and in-kind payments have lagged. This cultural lag has led to new economic vulnerabilities as laborers now depend solely on cash payments, whereas previously, wages often included food or grain, providing a more stable, secure income. The Green Revolution introduced modern technology, transforming the patron-client relationship in agriculture (Pertho, 2008). This shift has altered the employment practices of low-income workers who previously worked for a single owner. The wage patterns for agricultural day laborers have also changed. Traditionally, agricultural wages included both cash and in-kind payments, such as crops or food. Today, workers are hired on a daily or contract basis, allowing them to pursue additional income opportunities after completing their agricultural tasks. One Participent, Joad Ali (75) provides historical context to these changes.

''In 1970s, a farm laborer's daily wage included two meals and 5-10 taka, along with 2 kg of rice. Under the regimes of Zia and Ershad, laborers received two meals and 30-40 taka. By 2000-2010, wages rose to 70-150 taka plus a meal. Currently, daily wages range from 400-600 taka, sometimes even higher'' (KII).

Despite the rise in wages, the increased cost of labor has led to an even greater reliance on machinery. Although mechanization offers higher potential earnings, it has introduced instability and vulnerability among agricultural workers, who now face life risks and job insecurity absent in their traditional roles. Mechanization has improved agricultural efficiency, but it has also displaced many laborers, fundamentally altering the socio-economic dynamics within Dudhsar's farming community.

3.2.5. Lowered postharvest losses and enhanced profitability

The adoption of agricultural machinery has proven highly profitable for farmers, with investment costs typically recovered within two to three years (Hossain, 2009). As labor shortages continue to challenge the agricultural sector, there is an increasing reliance on modern technology to optimize farming processes across all stages of production, from tillage to threshing. This shift addresses not only labor scarcity but also enhances productivity and minimizes losses. In context Nazrul Islam (54) Said.

''A few years ago, the harvesting season posed significant challenges due to a shortage of labor, resulting in delays and considerable crop waste. However, with the advent and adoption of modern machinery, timely harvesting has become much more manageable. Additionally, irrigation can now be administered precisely when needed" (IDI).

This technological shift aligns with Eric Wolf's neotechnic ecotype, where the emphasis on market-oriented productivity drives the integration of efficient technologies to maximize crop output (Wolf, 1966). By adopting machinery, Dudhsar farmers are shifting from traditional reliance on manual labor typical of paleotechnic ecotypes to a model that leverages modern tools to enhance profitability and efficiency. Mechanization has not only boosted crop yields but has also significantly reduced postharvest losses by enabling timely harvests and precise resource management.

Before the widespread use of machinery, labor shortages often prevented timely harvesting, leading to crop waste and financial losses for farmers. Mechanization has alleviated these issues by ensuring that crops are harvested, dried, and stored efficiently, even in the face of labor constraints. To support this shift, the government subsidizes agricultural technologies at a rate of 30 percent, making them more accessible and appealing to farmers who seek both economic sustainability and increased productivity. One of the most transformative technological advancements in recent years is the combined harvester. This machine streamlines the harvesting process by simultaneously harvesting crops and separating grain from the husk. Its efficiency has led to widespread use in integrated farm management and small paddy field cultivation. Broadcast seeders are used for sowing seeds, applying fertilizers, and spraying pesticides. These machines ensure a uniform distribution, which enhances crop yields and reduces the dependency on manual labor. Seed drills precisely plant seeds in specific locations, ensuring optimal spacing and depth. Various types of dryers, including batch dryers, are employed to dry subsoil, paddy, wheat, corn, and other crop seeds. These technologies are vital for preparing seeds for storage and future planting, particularly in regions with high humidity. Power reaper machines significantly reduce the labor required for harvesting crops. They enable quicker and more efficient harvesting, alleviating the burden on farmers. One of the key informant, Parvez Mondal (35) stated,

''To grow vegetables like brinjal, chim, and tomatoes, regular pesticide application and irrigation are crucial for good yields. Modern spray machines allow for quick and timely pesticide application, improving crop outcomes. Additionally, mechanization in tasks like paddy cutting and threshing has significantly reduced crop losses that were once caused by labor shortages. The transition to modern agricultural technology is a critical strategy to address the labor crisis in the agricultural sector. By mechanizing labor-intensive tasks, these technologies not only reduce the reliance on human labor but also enhance productivity and efficiency''(KII).

From Ogburn's perspective, this shift reflects a cultural lag where the material aspect (the adoption of modern machinery) outpaces the non-material aspects of traditional farming practices and community reliance on manual labor (Ogburn, 1922). While mechanization increases profitability and reduces postharvest losses, it also introduces a cultural adjustment period as farmers adapt from a traditional labor-based model to a technology-driven approach. This cultural lag, however, is gradually diminishing as farmers increasingly recognize the advantages of mechanization in addressing labor shortages and improving economic outcomes. In sum, the transition to mechanized farming in Dudhsar has minimized crop losses and heightened profitability, reshaping the agricultural landscape from labor-intensive, self-sufficient practices to a productivity-oriented, technology-based system. This evolution underscores the socio-economic benefits of modern agricultural machinery, as farmers not only achieve higher yields but also gain greater financial stability by reducing their dependency on fluctuating labor availability.

3.2.6. The marginalization of women's labor

The adoption of mechanization reduces turnaround times between crops, reduces labor shortages during peak cropping periods, creates more working opportunities within rural and non-farm sectors, especially for women framers (Islam et al., 2016). However, before the advent of modern agricultural technology, human labor especially the contributions of central to the agricultural process. Men primarily handled tasks such as plowing, planting, and irrigating, while women were responsible for sustaining critical but often less visible aspects of farming. Traditionally, women's roles included seed preservation, which ensured continuity for the next planting season. They used containers like bottles, earthen pots, and polythene bags to store seeds safely, while also contributing to soil enrichment through composting. Organic fertilizers, often made from cow dung, kitchen ash, and leaves, were produced and applied by women, providing natural soil nutrients. Additionally, women played a key role in animal husbandry, taking care of oxen used for tilling fields, and in post-harvest processing, where tasks like boiling, drying, and storing crops ensured food security and quality. The introduction of modern technologies, such as chemical fertilizers, pesticides, and mechanized threshers, has significantly shifted these traditional roles. Tasks previously managed within households, for example seed preservation and fertilizer preparation, are now often outsourced to market transactions, diminishing the visibility and value of women's labor. This shift toward market dependency and mechanization aligns with Wolf's neotechnic ecotypes, where productivity and efficiency replace traditional, family-based farming roles. As agricultural inputs like fertilizers, seeds, and equipment are now acquired from the market, the autonomous and essential roles women once held are increasingly marginalized (Wolf, 1966). Ayesha Begum (55), shared her experiences of these changes:

''The men did the agricultural work, and we had to help with everything. Threshing the paddy, boiling the boiled paddy again, storing the seeds, taking care of the farm cows, drying the crops in the sun, storing all these things had to be done. And now whose wife does this? Now all the work is done by machines. Fertilizer, oil, seeds are bought from the market. Now we have to do less agricultural work'' (IDI).

Traditionally, women like her were essential in tasks such as threshing paddy, caring for farm animals, and storing crops. However, with the advent of technology, mechanization has significantly reduced the need for manual labor. Nowadays, tasks that once required considerable physical effort are accomplished with machines, and agricultural inputs are purchased from the market rather than produced on the farm. This shift highlights Ogburn's Cultural Lag Theory, as mechanization (the material culture) has advanced faster than non-material cultural adaptations recognizing women's roles and contributions in agriculture (Ogburn, 1922). The traditional, family-based farming model in which women's labor was essential has been replaced by a market-oriented approach, reducing the significance of women's contributions and potentially limiting their economic empowerment. The cultural lag between technological adoption and social adaptation has diminished women's involvement in agriculture, often reducing their visibility and value within the sector. While mechanization has improved productivity and efficiency, it has also led to the alienation of women from many traditional agricultural roles. This transition underscores the need to recognize and integrate the skills and labor contributions of women in both traditional and modern agricultural practices to ensure their continued participation and empowerment in the agricultural sector. Addressing this disparity is critical for maintaining a balanced, inclusive approach to agricultural modernization that values the diverse roles within farming communities.

3.3. Traditional knowledge in agriculture

Since ancient times, farmers have relied on traditional knowledge and innovative practices, often developed in response to environmental and socio-economic challenges. This agricultural expertise, passed down through generations, has been preserved within families and communities, with relatives and neighbors serving as sources of advice and support. Despite the expansion of modern agricultural technology, which has reduced the use of traditional methods in some areas, farmers in Dudhsar village continue to incorporate traditional knowledge into their farming. Practices such as seed collection, soil conservation, pest control, seed and crop storage, and land preparation are maintained alongside modern technologies. Farmers select seeds from insect-free crops, use traditional pest control methods in addition to pesticides, and engage in soil preservation techniques. This enduring reliance on ancestral wisdom demonstrates that even with access to modern

information, many farmers continue to uphold paleotechnic ecotypes as described by Eric Wolf, which emphasize self-reliance and sustainability through family-based practices (Wolf, 1966).

3.3.1. Land preparation

Proper land preparation is essential for successful crop production, and farmers in Dudhsar have relied on traditional methods to maintain soil fertility for generations. These methods include leaving crops on the land for a few days, cutting and burning weeds, and creating organic fertilizers from available resources. Additionally, when soil fertility decreases, farmers often rejuvenate the land by removing and replacing the topsoil. This blend of traditional practices and innate knowledge has sustained agricultural productivity for generations, even as modern farming methods become more prevalent. In this, Nazrul Islam (55), provides valuable insight into these traditional practices.

''He has been involved in agriculture since his childhood. He emphasizes the importance of traditional methods, explaining how removing topsoil from fields with reduced fertility has proven effective in boosting crop yields. According to Nazrul, this practice helps in replenishing the soil with nutrients, ensuring better production in subsequent planting seasons" (IDI).

This narrative highlights the enduring relevance of Cultural Lag Theory, as farmers maintain non-material cultural elements—such as traditional soil management methods alongside the material advancements of modern agriculture (Ogburn, 1922). Despite the introduction of chemical fertilizers and machinery, farmers like Nazrul continue to see value in ancestral practices, blending traditional and modern techniques to achieve a harmonious farming system that preserves soil health and ensures long-term productivity. By balancing tradition with modernity, farmers in Dudhsar village have created a resilient and effective farming approach. This blend not only supports sustainable agriculture but also maintains community identity and continuity, underscoring the importance of integrating both paleotechnic and neotechnic ecotypes in agricultural development. This approach illustrates how traditional practices continue to complement modern technology, offering a holistic strategy for sustainable crop production.

3.3.2. Seed collection

In agriculture, careful seed gathering and storage are essential procedures that local farmers have long engaged in (Ullah, 2024). In our study area, seed collection is a critical aspect of agricultural practices. The local farmers in this region employ traditional methods to ensure the sustainability and resilience of their farming. This practice reflects paleotechnic ecotypes, as described by Eric Wolf, where self-sufficiency and local knowledge form the backbone of farming (Wolf, 1966). The seed collection process involves selecting strong plants in the early stages of growth and preserving them until the end of the growing season. Farmers choose parts of crops that show good yield potential and, once mature, harvest and sun-dry these crops separately. Seeds from vegetables such as eggplant, beans, snake gourd, and pumpkin are collected and carefully dried under the sun. Paddy seeds are sun-dried two to three times before being stored in airtight containers, lined with dry neem leaves to prevent insect infestations. Twice yearly, the seeds are sun-dried again and repositioned in storage pots. During wet or rainy conditions, seeds are securely stored to avoid spoilage, ensuring their viability for the next planting season (Ullah, 2024). In this regard, Rashed Ali (50) said,

"Each year, I carefully select the best seeds from my harvest and store them in clay pots lined with ash to keep pests away. This method has helped maintain the quality and viability of the seeds over time"(IDI).

Similarly, another key informant, Aynal Haque (56), follows these traditional practices, which he learned from his father and neighbors. He meticulously chooses the healthiest and strongest seeds, sun-dries them, and stores them in clay pots with ash and neem leaves for pest control. These traditional seed collection practices reflect Ogburn's Cultural Lag Theory, where the material advancements in agriculture such as genetically modified and commercially produced seeds have not completely replaced non-material cultural practices like traditional seed preservation. Despite access to modern seeds and pesticides, farmers in Dudhsar continue to value their ancestral methods, preserving crop diversity and resilience. The seed collection practices in Dudhsar Village, as exemplified by Rashed Ali and Aynal Haque, highlight the importance of traditional knowledge in sustainable agriculture. Their experiences demonstrate how local methods contribute to agricultural resilience, food security, and the preservation of biodiversity. These practices not only sustain individual farming operations but also enhance the community's ability to adapt to climate variability and environmental changes and climate variability. This continued reliance on traditional methods, despite the availability of modern alternatives, emphasizes the cultural and practical significance of local knowledge, maintaining a balance between sustainable self-sufficiency and modern agricultural advancements.

3.3.3. Climate change and environmental management

Rapid climate change has garnered significant attention over the last three decades due to its swift changes and harmful effects on both human life and the environment (Orlove & Brush, 1996). This issue has become a global and local hot topic

because of its detrimental impacts. The main concerns and inquiries focus on the pace of these changes. The effects of rapid climate change have begun to touch various facets of human life, including alterations in agricultural practices like crop selection, timely harvesting, and technological use, dietary patterns, and quality of life (Pender, 2010). Local populations, particularly in Bangladesh, have expressed concern about climate change, with their perceptions influenced by local climatic changes, including altered agricultural practices and biodiversity loss (Sillitoe, 2006). In our study area, we observed farmers using their practical knowledge to protect against the impacts of climate change. This section presents two case studies emphasizing how local farmers have adapted to these changes.

Zoad Ali, a 65-year-old farmer recalls how the timing of seasons has shifted over the years, affecting crop cycles and productivity. Zoad emphasizes the value of traditional farming methods passed down through his family. He uses organic fertilizers made from compost and relies on hand hoeing and seedbed preparation techniques that have sustained his farm's fertility for decades. Despite the challenges posed by increased temperatures and irregular rainfall patterns, he adherence to traditional practices has helped maintain soil health and crop yields. His experience highlights the resilience of indigenous farming knowledge in adapting to climate change (Case-2).

This case exemplifies the paleotechnic ecotype described by Eric Wolf, where local knowledge and sustainable practices are prioritized over industrialized methods, highlighting self-reliance and ecological harmony (Wolf, 1966). Zoad's resilience in the face of climate adversity demonstrates how traditional practices can contribute to environmental management. His experience shows the importance of non-material cultural practices such as sustainable soil management and organic composting that help preserve soil health amid changing environmental conditions. This case aligns with Ogburn's Cultural Lag Theory, as Zoad's non-material cultural adaptations (his family's sustainable methods) have kept pace with climate change, even as some aspects of modern agriculture struggle to address such challenges (Ogburn, 1922).

Arman Sheikh (54), *another farmer rooted in traditional practices, acknowledges the benefits of modern agricultural tools, such as chemical fertilizers and mechanized equipment, but remains committed to traditional methods. To address climate variability, he experiments with different crop varieties, crop rotation, and composting. His reliance on organic fertilizers and manual weed management has helped his farm become more resilient to extreme weather (Case, 3).*

This practices illustrate an integration of neotechnic ecotypes with paleotechnic strategies, blending traditional resilience with selective adoption of modern techniques. This approach highlights the balance between preserving ancestral knowledge and adopting technology that aligns with sustainable agriculture. Arman's adaptability underscores the potential of blending traditional and modern methods to create a farming system resilient to climate shifts. These two case studies provide a comprehensive understanding of the role of traditional knowledge in agricultural practices and environmental management in agricultural practices. Their experiences focus the importance of preserving and integrating traditional wisdom with modern techniques and underscore the significance of community-based adaptation measures. These case studies offer a compelling case for incorporating indigenous knowledge into broader environmental management policies to enhance resilience and sustainability in the face of climate change.

4. Discussion

Technological influence on agricultural practices all over the world and in Bangladesh it carries great. Researches have explored the adoption of new technologies and their impact on yields and productivity (Islam et al., 2016; Rahman et al., 2021). Several studies have investigated the repercussions of mechanization on the broader livelihoods of agrarian communities (Miah et al., 2002; Wohab 2012; Fuad & Flora, 2019). Findings from these studies suggest that the escalated adoption of small-scale mechanization, and to a certain extent, mechanization in general, has significantly impacted the income of small-scale farmers and landless laborers. Previous studies have predominantly highlighted the effects of agricultural mechanization, noting both its positive and negative impacts on the agricultural sector. Our research supports these findings but also reveals a deeper, less explored issue: the advent of modern agricultural technology, specifically the mechanization of agriculture, has introduced a significant cultural conflict among farmers. Our findings indicate that farmers are struggling to fully adopt and effectively utilize modern agricultural technologies, remaining partially tethered to traditional farming practices. This dichotomy has created a state of cultural conflict, hindering agricultural development. This phenomenon aligns with Ogburn's theory of cultural lag, which posits that material and non-material elements of culture do not progress synchronously, resulting in societal issues (Ogburn, 1922). In our context, the material aspect (modern agricultural technology) has advanced, but the (non-material aspect) the cultural and social adaptation to this technology lags behind. This lag creates a discord that not only prevents farmers from maximizing the benefits of mechanization but also stymies overall agricultural progress. Despite having ample cultivable land, the inability to harmoniously integrate modern technology with traditional practices is obstructing the achievement of our agricultural objectives. This cultural conflict is manifesting in several ways. Firstly, there is a notable resistance to change among the farming community, rooted in a strong attachment to traditional farming methods.

Secondly, the lack of adequate training and support for farmers in using new technologies exacerbates their struggle. We observed the shift towards market dependency in Dudhsar village's agricultural practices represents a broader trend of modernization and commercialization in rural farming communities. This transition has both positive and negative implications

for the farmers. On the positive side, the use of high-yielding seeds and modern agricultural inputs has likely increased crop productivity and potential income. The expansion of social networks to include various market actors and NGO workers can provide farmers with better access to resources, information, and support services. However, this dependency on the market also introduces vulnerabilities. The increased production costs associated with modern agricultural practices necessitate the need for external funding, often through loans. While these loans provide necessary capital, they also pose financial risks, particularly if crop yields are poor or market prices fall. The reliance on market-purchased inputs can reduce the autonomy of farmers, making them more susceptible to market fluctuations and price increases for essential agricultural materials. Moreover, the traditional self-sufficient farming practices, which were more sustainable and less dependent on external inputs, are being replaced. This shift can lead to a loss of traditional knowledge and practices that were adapted to local conditions and were more environmentally friendly. While modern technology has undoubtedly enhanced productivity and efficiency, it has also introduced new challenges, including increased costs, market dependency, and labor displacement.

5. Conclusions

This study provides a comprehensive analysis of the transition from traditional to modern agricultural practices in the agrarian community. The findings elucidate how agricultural mechanization, influenced by governmental policies and market forces, has significantly transformed the farming landscape over the years. One of the key insights from this study is the substantial increase in agricultural productivity and efficiency brought about by modern machinery and technology. The introduction of high-yielding variety seeds, irrigation pumps, power tillers, and combined harvesters has revolutionized farming practices, enabling year-round cultivation and higher crop yields. However, this transition has also escalated production costs, making farming more capital-intensive. Farmers now heavily rely on market systems for inputs such as seeds, fertilizers, pesticides, and machinery, which were previously sourced within the community. This dependency on the market has financial implications, necessitating loans from NGOs and other financial institutions to sustain agricultural activities. The shift towards mechanization has also led to significant changes in labor dynamics. The reliance on modern agricultural machinery has reduced the need for human labor, particularly affecting the roles traditionally held by women. Tasks that were once integral to women's contributions, such as seed preservation, organic fertilizer application, and crop processing, have been largely replaced by mechanized processes. This marginalization of women's labor underscores the need for policies that recognize and integrate their contributions within modern agricultural frameworks. Despite the pervasive influence of modern technology, traditional agricultural knowledge remains a crucial component of farming practices in Dudhshar village. Farmers continue to employ traditional techniques for seed selection, pest control, and land preparation, demonstrating a hybrid approach that leverages both traditional wisdom and modern innovations. This resilience and adaptability highlight the importance of preserving indigenous knowledge systems even as agricultural practices evolve.

Ethical Considerations

We took oral consent from the respondents and in case of deny we took interview from another. In addition, we used pseudonyms of the respondents in this study.

Conflict of Interest

All authors declare that they have no connections or associations with any organizations or entities that have a financial or nonfinancial stake in the subject matter or materials covered in this article.

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