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Capital Meets Cultivation: Agricultural Transformation in Assam's Kamrup (Rural) District.

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Abstract
The transformation of agriculture through capital-intensive technology has significantly reshaped farming practices in India. This study examines the impact of such technological advancements in the Kamrup (Rural) district of Assam, focusing on the adoption of High Yielding Varieties (HYVs), mechanization, irrigation facilities, and agricultural extension services. Despite the introduction of capital-intensive technology, the transformation has been partial, with limited crop diversification and infrastructural challenges. The research, conducted through a field survey of 90 farming households across six villages, highlights the uneven distribution of modern agricultural inputs, financial constraints, and the farmers' reliance on traditional crops, primarily rice. While mechanization and irrigation have improved productivity, challenges such as the high cost of farm inputs, inadequate institutional credit access, and lack of efficient marketing channels persist. The study underscores the need for enhanced government intervention in infrastructure development, streamlined credit facilities, and improved agricultural extension services. It advocates for increased farmer awareness and integration of information technology to optimize farming decisions and market access. Ultimately, the research suggests that a holistic approach encompassing technological, financial, and institutional support is essential for sustainable agricultural transformation in Assam.

Keywords: Agricultural transformation, capital-intensive technology, High Yielding Varieties, mechanization, Assam.

1. Introduction:

1.1 Conceptual Background:

Technological advancements in agriculture, particularly the adoption of capital-intensive technology, have significantly transformed the sector in recent years. Traditional agricultural practices, which largely relied on animal power, have gradually evolved into modern, technology-driven farming systems. Many developed nations now extensively incorporate advanced, capital-intensive technologies in agriculture, leading to increased productivity and efficiency (Balasubramanyam, 1984).

In the Indian context, the initial fifteen years of economic planning (1951–1965) were primarily focused on institutional reforms in agriculture, emphasizing an integrated rural development approach. These initiatives included cooperative farming, community development programs, and land reforms. However, due to multiple challenges such as the inefficacy of cooperative farming models and an increasing scarcity of food, India's agricultural policy underwent a significant shift in the mid-1960s. The focus transitioned from institutional reforms to a technology-driven agricultural production approach, prioritizing the application of modern science and technology, along with substantial investment in inputs and price incentives to encourage farmers' adoption of new techniques (Balasubramanyam, 1984).

A pivotal element of this technological transformation was the introduction of High-Yielding Varieties (HYVs) of crops, which played a crucial role in revolutionizing agricultural productivity. These HYVs, developed in the mid-1960s, were designed to produce substantially higher yields than traditional varieties, provided they were cultivated using complementary inputs such as fertilizers and irrigation. Consequently, this technology became widely known as the HYV seeds-fertilizer-water package (Chaoudhuri, 1978). These new crop varieties exhibited unique physiological attributes, including efficient nutrient absorption, shorter maturation periods, and independence from daylight duration, making them highly suitable for intensive farming (Bezbaruah, 1994).

Despite these advancements, the impact of capital-intensive agricultural technologies was not uniform across India. The Green Revolution primarily benefited states such as Punjab, Haryana, Maharashtra, West Bengal, and western Uttar Pradesh, while other regions, including Assam, experienced a slower adoption rate. Furthermore, the growth in agricultural productivity was particularly pronounced for wheat, whereas the diffusion of technology to rice cultivation and other crops progressed at a much slower pace (Balasubramanyam, 1984).

Given this uneven spread, it is essential to examine the role of capital-intensive agricultural technology in the development of Assam's Kamrup (Rural) district. This study focuses on farmers in the Rangia, Hajo, and Palashbari circles of the

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district, where modern farming techniques, including the use of HYV seeds, mechanization, and government-subsidized shallow tube well (STW) irrigation systems, have been adopted to some extent. The study aims to evaluate the extent to which these technological interventions have enhanced agricultural productivity, improved farmers' income levels, and contributed to their overall standard of living.

1.2 Literature Review

Agricultural transformation through capital-intensive technology has been a widely researched topic, particularly in the context of developing economies like India. The evolution of modern farming techniques, the role of capital-intensive inputs, and their impact on productivity, income, and rural livelihoods have been analyzed extensively. This literature review examines key studies on the adoption and diffusion of agricultural technology, its implications for rural economies, and the specific challenges faced in the northeastern region of India, with a focus on Assam's Kamrup (Rural) district.

The introduction of capital-intensive technology in agriculture marks a significant departure from traditional farming practices. Before the mid-20th century, agricultural production in most developing countries, including India, was characterized by manual labor, animal power, and traditional seed varieties (Hayami & Ruttan, 1985). However, the post-World War II period saw increased research in agricultural sciences, leading to the development of high-yielding varieties (HYVs), chemical fertilizers, pesticides, and mechanized irrigation systems (Evenson & Gollin, 2003).

The Green Revolution of the 1960s was a turning point in Indian agriculture, driven by capital-intensive technological innovations such as improved seed varieties, chemical fertilizers, and modern irrigation methods (Hazell, 2009). The new technology package, often referred to as the HYV-fertilizer-water package, significantly increased food grain production, particularly wheat and rice, in select regions of India (Chakravarti, 1973). However, the benefits of these technological advancements were not uniformly distributed across the country, with states like Punjab, Haryana, and western Uttar Pradesh witnessing rapid transformation, while northeastern states, including Assam, lagged in technological adoption (Chand & Parappurathu, 2012).

Several studies highlight the positive impact of capital-intensive agricultural technologies on farm productivity and rural incomes. According to Feder, Just, and Zilberman (1985), the adoption of new agricultural technology led to increased yield levels and overall farm efficiency. Similarly, Pingali (2012) argues that modern agricultural technologies not only improved food security but also played a crucial role in poverty reduction.

In India, empirical studies indicate that farmers who adopted mechanized farming techniques and HYV seeds experienced a rise in productivity and profitability (Singh, 2002). For example, in Punjab and Haryana, wheat yields increased from 1,000 kg/ha in the early 1960s to over 4,000 kg/ha by the 1990s, demonstrating the transformative potential of capital-intensive farming (Sidhu & Byerlee, 1992). However, these benefits were not uniform across all farming communities, as resource-poor farmers often struggled to afford the expensive inputs required for modern farming (Fan, Gulati, & Thorat, 2008).

While the Green Revolution led to remarkable agricultural growth in certain states, many regions, particularly in eastern and northeastern India, did not experience the same level of technological diffusion (Bhalla & Singh, 2009). Assam, with its unique agro-climatic conditions and fragmented landholdings, was slower to adopt capital-intensive agricultural practices. Several studies attribute this slow adoption to infrastructural constraints, lack of credit access, and inadequate extension services (Bezbaruah, 1994; Sharma, 2007).

Studies on Assam's agricultural sector suggest that while HYV seeds and mechanization have made inroads in select districts, the overall pace of technological adoption has been sluggish (Dutta & Kashyap, 2014). Additionally, the predominance of rice cultivation in Assam presents unique challenges, as rice requires significant water resources, and the region is prone to floods and erratic rainfall patterns (Saikia, 2013). These factors have contributed to the limited diffusion of capital-intensive farming techniques in Assam compared to other states.

Government interventions have played a crucial role in promoting capital-intensive agriculture in India. Policies such as minimum support prices (MSP), input subsidies for fertilizers and irrigation, and rural credit schemes have incentivized farmers to adopt modern farming practices (Gulati & Fan, 2007). However, research indicates that these benefits have been disproportionately concentrated in regions with better infrastructure and political influence (Binswanger & Quizon, 1989).

In Assam, government initiatives such as the provision of subsidized shallow tube wells (STWs) and mechanized farm equipment have facilitated the gradual adoption of modern technology (Bora, 2015). However, empirical evidence suggests that many small and marginal farmers in Assam still face difficulties in accessing credit and technical know-how, limiting their ability to invest in capital-intensive farming (Hussain & Sengupta, 2016).

The socio-economic implications of capital-intensive agriculture extend beyond yield improvements. Research indicates that regions with high levels of mechanization and technological adoption have witnessed better income growth, improved rural employment opportunities, and enhanced living standards (Hazell & Ramasamy, 1991). In Punjab and Haryana, increased agricultural productivity led to rising rural incomes and better access to education and healthcare services (Singh, 2000).

However, the scenario in Assam presents a different picture. While some districts, including Kamrup (Rural), have shown signs of agricultural modernization, the extent of transformation remains limited. According to Bezbaruah (1994), farmers

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in Assam have benefited from technology adoption primarily through higher productivity, but income disparities persist due to unequal access to resources. Small and marginal farmers, who constitute a significant portion of the agrarian population, often lack the financial capacity to invest in high-cost inputs, making them dependent on government support or informal credit sources (Saikia, 2017).

Furthermore, the shift to capital-intensive farming has implications for labour dynamics. Studies show that mechanization, while increasing efficiency, has also led to labour displacement in some cases (Sharma, 2012). In Assam, where agricultural labour forms a significant part of the rural workforce, increased mechanization without alternative employment opportunities poses potential socio-economic challenges.

The widespread adoption of capital-intensive technology has also raised concerns about environmental sustainability. Research highlights that the overuse of chemical fertilizers, excessive groundwater extraction, and mono-cropping practices have led to soil degradation, water scarcity, and loss of biodiversity (Pretty, 2008). In Punjab and Haryana, for example, intensive wheat-rice cropping systems have resulted in declining groundwater levels and increased soil salinity (Sharma & Chauhan, 2008).

In Assam, concerns regarding the sustainability of modern agricultural practices have also been raised. Studies suggest that excessive reliance on chemical inputs, coupled with the region's vulnerability to climate variability, could pose long-term challenges for sustainable agriculture (Deka & Mahanta, 2015). Therefore, researchers advocate for a balanced approach that integrates traditional ecological knowledge with modern agricultural techniques to ensure long-term productivity without compromising environmental integrity.

While considerable research has been conducted on agricultural transformation in India, specific studies focusing on Assam's rural districts, particularly Kamrup (Rural), remain limited. The main research gap is that most existing literature examines broad patterns of agricultural development but lacks micro-level analyses of how capital-intensive technology impacts smallholder farmers in Assam. Further research is needed to assess the economic viability of modern farming techniques, the role of institutional support, and the socio-economic implications of agricultural transformation at the grassroots level. To fill this research gap, the following research questions have been formulated: i) How has the adoption of capital-intensive technology transformed farming in Kamrup (Rural), and what impact has it had on productivity and farmer livelihoods? ii) Is the necessary agricultural infrastructure available in Kamrup (Rural) to support this transformation, and what challenges do farmers face in accessing it?

1.3. **Objective:**

The main objectives of this study are to:

(i) to understand the extent of agricultural transformation that might have evolved among the farmers of Kamrup district through adoption of capital-intensive technology in agriculture.

(ii) to investigate the availability of the basic infrastructure necessary for agricultural transformation

2. Methods:

This study adopted a mixed-method approach to achieve its objectives. For data collection from the artisans, the layering method was applied. In the first layer, three revenue circles were identified from the Kamrup Rural District: Rangia, Hajo, and Palashbari. These circles were strategically selected to ensure comprehensive district coverage, with Rangia located in the extreme northern part, Hajo in the central region, and Palashbari in the southern part. In the second layer, two villages were selected from each revenue circle, resulting in a total of six villages. (What is the justification of choosing these two villages?) In the third layer, from each village, fifteen households were identified using the snowball sampling technique. Since a predefined sampling frame for farmers was unavailable, respondents were selected through references. The first household in each village was identified with the assistance of the Gaonburah, who recalled potential respondents as no official list of farmers was available. Subsequently, each identified farmer referred the next respondent, and this process continued until fifteen households per village were selected. The same procedure was followed for the remaining villages, leading to a total of ninety respondents being interviewed.

Table 2.1: Layering stages

1st Layer	**2nd Layer**	**3rd Layer**
Selection of the Revenue Circle	Selection of the villages	Selection of the household
Three Revenue circles were selected based on the spatial distribution of the geography. The Revenue Circles were Rangia Circle, Hajo Circle and Palashbari Circle.	Two villages were selected from each Revenue Circle mentioned in the1st Layer. Therefore, 6 villages were selected based on the records kept by the Revenue Circle. Villages Balagaon and Dhoulkuchi are chosen from Rangia Revenue Circle, Villages Singimari and Ujanguri, chosen from Hajo Revnue Circle and villages Tiniali, and Cimia, from Palashbari Revenue Circle.	15 households were selected based on snowball sampling from the 6 villages as mentioned in the 2nd layer.

To collect data from each household, a well-structured interview schedule was designed. During the pilot survey, it was observed that due to low literacy levels and the busy schedules of farmers, they were reluctant to complete questionnaires.

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Since interview schedules yield higher response rates compared to self-administered questionnaires, this method was deemed more effective (Goyder, 1985; Rindfuss, Choe, Tsuya et al., 2022). Several factors justified the choice of interview schedules as the primary data collection tool. Interviews allowed for flexibility in adapting questions based on respondents' answers, enabling a deeper exploration of topics and better clarification of responses, ultimately leading to richer data. The ability to provide immediate clarifications helped minimize misunderstandings, ensuring comprehensive and accurate data collection. Furthermore, response rates were significantly higher in face-to-face interviews compared to self-administered questionnaires, as personal engagement encouraged participation. Building rapport was also easier through interviews, making respondents feel more comfortable and willing to share information, which contributed to more honest and open responses. Additionally, non-verbal cues such as body language, facial expressions, and tone of voice provided valuable contextual insights. Interviews proved to be particularly effective for complex or open-ended questions, ensuring respondents fully understood the inquiries. They also overcame literacy barriers, allowing those with reading or writing difficulties to participate without constraints. The possibility of immediate feedback and real-time question adjustments reduced ambiguities and enhanced data quality.
By integrating both closed-ended and open-ended questions, this approach facilitated the collection of quantifiable data alongside rich, qualitative insights, ensuring a comprehensive understanding of the research topic. The mixed-method approach further incorporated qualitative methods, observations, literature reviews, and stakeholder opinions, enabling effective data triangulation. Cross-verification of information from multiple sources strengthened the reliability and validity of the findings (Rugg, 2010; Bhandari, 2022).
The interview schedule was structured into two sections: the village schedule and the household schedule. The village schedule captured essential village-level information, including the name of the village and district, the total number of households and farm households, the total population, and the availability of basic infrastructure such as electricity and road connectivity. It also recorded the distance of the village from various essential facilities, including educational institutions, healthcare centers, markets for agricultural produce, transport and communication services, banking and financial institutions, and township access. The household schedule focused on individual household details, covering demographic, economic, and agricultural aspects. This structured methodology ensured comprehensive and reliable data collection, providing an in-depth analysis of the research subject. For quantitative analysis, average mean, multiplication, division, percentage etc. have been used.

3. Results and Discussions:

3.1 Extent of Agricultural Transformation

The extent of agricultural transformation among the sample farmers can be analysed based on factors such as farm size, adoption of new High-Yielding Variety (HYV)-fertilizer-water technology, and level of agricultural investments. These aspects are discussed below in detail.

Table 3.1 Cropping pattern in study area

Circles / Crops	Rangia		Hajo		Palashbari		Total	
	Area (in hec)	**Percentage**	**Area (in hec)**	**Percentage**	**Area (in hec)**	**Percentage**	**Area (in hec)**	**Percentage**
Autumn Rice	0.00	0.00	7.07	22.56	0.00	0.00	7.07	8.62
Winter Rice	21.07	70.85	18.13	57.87	17.20	82.17	56.4	68.78
Summer Rice	8.67	29.15	6.13	19.57	3.73	17.83	18.53	22.06
Rice Total	*29.74*	*78.82*	*31.33*	*62.83*	*20.93*	*62.54*	*82.00*	*67.73*
Wheat	0.00	0.00	0.00	0.00	0.13	0.11	0.13	0.11
Oilseeds	0.67	1.77	3.33	6.68	1.20	3.59	5.20	4.30
Vegetables	5.60	14.84	8.27	16.58	6.80	20.32	20.67	17.07
Potato	1.60	4.24	4.40	8.82	2.13	6.37	8.13	6.72
Jute	0.00	0.00	2.93	5.88	2.40	7.17	5.33	4.41
Sugarcane	0.00	0.00	0.00	0.00	0.13	0.40	0.13	0.11
Others Total	***7.87***	***21.18***	***18.93***	***37.17***	***12.79***	***37.46***	***39.59***	***32.27***
Total	**37.61**	**100.00**	**50.26**	**100.00**	**33.72**	**100.00**	**121.59**	**100.00**

3.1.1 Operational Holding and Cropping Intensity

One of the key factors influencing agricultural transition among farmers is the size of operational holdings and their efficient utilization in farming. Operational holdings differ from ownership holdings in that the former refers to the land available to the farmer, including both owned and leased-in land that is put under cultivation during the study period, while the latter refers to the total land owned by an individual, regardless of whether it is utilized for cultivation. Cropping intensity, which refers to the extent to which land is utilized for crop production activities over a given period, serves as

an indicator of agricultural progress. It is expressed as the ratio of the gross cropped area to the net cropped area, represented in percentage terms (Kanthamma, 1997, p. 125; Daimari, 2011, pp. 114-115).
The study found that rice cultivation accounted for approximately 68% of the total cropped area among the sample farms, while the remaining 32% was allocated to other crops such as wheat, oilseeds, potatoes, tomatoes, garlic, vegetables, jute, and sugarcane. Cropping intensity, defined as the number of crops grown on a particular plot of land within an agricultural year (calculated as), was found to be 129.95%, which is not a particularly promising sign.
Crop diversification from subsistence-oriented rice cultivation to market-oriented crops such as jute, mesta, sugarcane, vegetables, oilseeds, and tomatoes has been slow in the three selected circles. Rice remains the principal crop in these areas. In Rangia Circle, approximately 78.82% of the total cropped area was allocated to rice, with only about 21% used for other crops. Similarly, in Hajo Circle, around 63% of the total cropped area was utilized for rice cultivation, while about 37% was allocated to other crops. In Palashbari Circle, more than 62% of the total cropped area was dedicated to rice, whereas 38% was used for cultivating other crops. These findings indicate that the farmers of Palashbari and Hajo circles have slightly outpaced those of Rangia Circle in terms of crop diversification.

3.1.2 Level of Shift in Farming Technology

Most farmers who adopted HYV seeds primarily cultivated rice. However, in Singimari village, a significant number of farmers were found to be growing heirloom tomatoes. According to Anderson (2019), heirloom varieties are often open-pollinated, meaning they are naturally pollinated by insects or wind and maintain their genetic traits from one generation to the next. This biodiversity contributes to their robustness and ability to adapt to local environmental conditions.
A total of 85 out of 90 sampled farmers (94.44%) had adopted HYV rice, covering nearly 75% of the total area under HYV crops. Moreover, over 74% (70 farmers) of the sampled population cultivated winter and summer vegetables of high-yielding varieties, covering approximately 18.28% of the total area under HYVs. However, farmers in Singimari village relied heavily on heirloom tomato seeds. Additionally, 44.12% of the sampled farmers engaged in HYV potato cultivation, which covered about 5.03% of the area under HYVs. Furthermore, 11.64% of the sampled farmers adopted HYV oilseeds, covering about 1.72% of the total HYV area, while 1.47% cultivated HYV sugarcane, which accounted for only 0.12% of the total HYV area.
These findings suggest that while there has been a moderate shift in farming technology from traditional to modern methods among the sample farmers in Kamrup district, the shift has predominantly been toward HYV rice. In the case of HYV rice, winter varieties occupied approximately 69.34% of the total area under cultivation in 2023-24, whereas summer and autumn varieties accounted for 22.79% and 7.87%, respectively. Overall, the percentage of the total cropped area under HYV rice stood at 99.19%. Among the selected circles, farmers in Rangia and Palashbari fully allocated their rice acreage to HYV rice, while those in Hajo Circle used HYVs on about 98% of their total rice acreage. The most cultivated HYV rice varieties included Pankaj, Aijong, Bahadur, Piolee, Lachit, Lohit, Arise, MPU Chandra Mashuri, Jaya, Jaimati (Mala), and Topchini.

3.1.3 Use of Chemical Fertilizers

The use of adequate fertilizer inputs is crucial for the successful cultivation of HYV crops. According to the Economic Survey of Assam (2022), the state's average fertilizer consumption stands at approximately 140.60 kg per hectare. The study found that all sample farmers who adopted HYV seeds also used fertilizers. The fertilizer consumption among the sample farms was above 200 kg per hectare of cultivated land, significantly exceeding the state average.
Among the selected study areas, the highest fertilizer consumption per hectare of combined crops was recorded in Rangia Circle at 261.25 kg, while the lowest was observed in Hajo Circle at 153.17 kg. A closer analysis revealed that farmers in Rangia and Palashbari Circles applied a higher proportion of fertilizers to non-rice crops, whereas those in Hajo Circle applied relatively more fertilizers to rice crops than to other crops.

3.1.4 Mechanization of Agriculture

Mechanization is a key driver of agricultural transformation. In the study areas, tractors, power tillers, and power pumps were the only mechanized tools used by farmers. Consequently, mechanized farming among these farmers primarily involved mechanized plowing using tractors and mechanized irrigation through power pumps.
The study revealed that 47 out of 90 sample farm households (52.22%) owned power tillers, while an additional 30 farm households hired tractors or power tillers for cultivation. This means that 80 out of 90 sample farms (88.88%) practiced mechanized plowing. Farmers in Hajo Circle exhibited a relatively higher rate of mechanized plowing compared to those in Palashbari and Rangia Circles, who largely depended on tractor or power-tiller plowing.
Regarding mechanized irrigation, the study found encouraging trends. All sample farms employed shallow tube well (STW) irrigation systems. Of the 90 sample farmers, 82 owned their STW systems, while the remaining eight hired irrigation services from others. As a result, the sample farmers in the study area were not reliant on monsoon rains for cultivation, demonstrating a significant level of irrigation independence.
The study highlights the extent of agricultural transformation among the sample farms by examining operational holding size, cropping intensity, adoption of farming technology, use of fertilizers, and mechanization levels. The findings reveal

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that while there has been progress in adopting HYV seeds and mechanization, the transition toward crop diversification remains slow. Rice continues to be the dominant crop, with limited movement toward market-oriented crops. The adoption of fertilizers has surpassed the state average, and mechanization has significantly improved through the use of power tillers and STW irrigation. Despite these advancements, further efforts are needed to promote crop diversification, enhance mechanization, and optimize fertilizer use for a more sustainable and profitable agricultural system in Kamrup district.

3.2 Infrastructure for Agricultural Transformation

3.2.1 Availability of Modern Farm Inputs

The availability of farm inputs plays a crucial role in the adoption of new agricultural technology and the transformation of farming practices. Effective use of these inputs by farmers depends largely on their accessibility at reasonable prices and the farmers' knowledge of their application. Ensuring the availability of farm inputs at nearby locations, coupled with training facilities for proper usage, can significantly encourage farmers to adopt modern farming techniques.

Among the sample farmers surveyed, 88 (97.77%) reported using purchased High-Yielding Variety (HYV) seeds, while only one farmer (1.47%) used self-owned seeds. A notable exception was observed in the Singimari area of Assam, where a farmer practiced heirloom seed cultivation for tomatoes. Fertilizer outlets were found to be located, on average, three kilometers from the sample villages. All 90 surveyed farmers purchased and used fertilizers and pesticides on their crops. Other essential farm inputs, including ploughs, spray machines, and various farm implements, were available from traders situated at an average distance of ten kilometers from the sample villages. Given that these inputs are fundamental to farming operations, most farmers purchase them annually or biennially.

Table 3.2 : Irrigated land in the sample farms (in hectares)

Circles	STWs/LPP		DTWs		Other Minor		Major/ medium		Total
	High land	Low land	High land	Low land	High land	Low land	High land	Low land	
Rangia	9.47	22.27	0.00	0.00	0.00	3.33	0.00	0.00	35.07
Hajo	12.27	20.93	0.00	0.00	0.00	1.33	0.00	1.33	35.86
Palashbari	10.27	20.40	0.00	0.00	0.40	1.20	0.00	0.00	32.27
All Circles	**32.01** *(31.02)*	**63.60** *(61.63)*	**0.00** *(0.00)*	**0.00** *(0.00)*	**0.40** *0.39)*	**5.86** *(5.68)*	**0.00** *(0.00)*	**1.33** *(1.29)*	**103.20**

Since private traders predominantly supply these farm inputs, farmers can purchase them as needed without significant shortages. However, when the same inputs are distributed by government agencies, delays may occur due to inefficiencies in the distribution process and policy-related issues. These delays often create barriers for farmers in acquiring necessary inputs on time, thereby affecting their farming efficiency.

3.2.2 Water Supply Facilities in Agricultural Fields

An assured water supply in agricultural fields is one of the most critical factors influencing agricultural improvement. Inadequate irrigation facilities compel farmers to rely entirely on rainfall, making their agricultural activities vulnerable to climatic variations. The study examined the distribution of irrigation facilities among the sample farms across three selected circles in Kamrup District.

All 90 sample farms had irrigation facilities covering a combined net cultivated area of 103.20 hectares. This development represents a significant improvement in the agricultural landscape of the district. Data from Table 4.2 indicate that Small Tube Wells (STWs) and Lift Pumping Points (LPPs) provided irrigation to approximately 95.61 hectares, accounting for 92.65% of the total cultivable land of the surveyed farms. Other minor irrigation sources, such as small dam-canals and river-bandhs, provided irrigation to only about six hectares, representing 6.07% of the total irrigated area. Major and medium irrigation facilities covered just 1.33 hectares (1.29%). Notably, government-operated Deep Tube Well irrigation was entirely absent among the sample farms.

3.2.3 Agricultural Extension Services

Effective agricultural extension services are crucial for transforming traditional agricultural practices. These services enhance the efficiency of input utilization, thereby increasing farm output. The study found that agricultural extension services among the sample farms were satisfactory.

Regarding the selection of crop varieties, 29.41% of the sample farmers reported receiving guidance from Village Level Extension Workers (VLEWs). When it came to the use of fertilizers, 85.29% of farmers relied on advice from agricultural extension officers. Additionally, VLEWs played a significant role in guiding farmers on pesticide application, including type, timing, and quantity. More than 82% of the farmers followed VLEW recommendations for pesticide application, while over 16% consulted fellow farmers, and only about 1.47% depended on personal experience.

In other farming aspects, such as cultivation timing, seasonal adjustments, and irrigation scheduling, 89.71% of the farmers sought advice from VLEWs. The strong engagement of VLEWs with farmers indicates a high level of familiarity and trust, resulting in improved adoption of modern farming techniques. By providing logistical support and transferring knowledge on modern agricultural practices, VLEWs have significantly contributed to the transformation of traditional agriculture in the study area.

3.2.4 Sources of Agricultural Finance

Financial resources are a crucial component of agricultural operations, determining a farmer's capacity to invest in inputs, technology, and infrastructure. The study revealed that the majority of sample farmers relied on self-financing for agricultural activities. Specifically, 88.12% of farmers financed their operations independently, while only 11.88% relied on loans from institutional and non-institutional sources during the 2009-10 agricultural year.

A significant portion of agricultural income was reinvested into farming activities, with approximately 21% of earnings from farm produce sales channeled back into agriculture. The remaining 79% was used for investments in other sectors and household expenditures. The study also observed regional variations in reinvestment patterns. Farmers in the Hajo circle demonstrated a higher tendency to reinvest their agricultural earnings in farming compared to those in Rangia and Palashbari. The substantial diversion of agricultural income into other sectors suggests an increasing interlinkage between agriculture and other economic domains, potentially encouraging farmers to explore non-farm occupations.

The accessibility and affordability of agricultural credit play a critical role in determining borrowing behavior among rural farmers. High-interest rates tend to discourage borrowing, while lower rates promote access to financial resources. However, many rural farmers, particularly those who are illiterate, face difficulties navigating institutional loan processes. Consequently, they often resort to borrowing from village moneylenders, who typically charge exorbitant interest rates.

Interest rates on agricultural credit from non-institutional sources were found to be alarmingly high. In Rangia Circle, the rate stood at 24% per annum, while in Hajo Circle, it was as high as 44%. In Palashbari Circle, the rate was 28%, resulting in an average interest rate of 32% across the study area. In contrast, institutional agricultural loans had an average interest rate of 13%, ranging between 10% and 13% per annum. The relatively high interest rates from non-institutional sources underscore the financial challenges faced by rural farmers, necessitating improved access to institutional credit with simplified procedures.

3.2.5 Marketing Facilities for Agricultural Products

Efficient marketing facilities and favorable government pricing policies play a vital role in incentivizing farmers to adopt high-yielding variety crops. Access to competitive markets enables farmers to secure better prices for their produce, ultimately encouraging improvements in farming practices.

The study identified two primary marketing channels available to sample farmers: (i) traders in urban and semi-urban areas and (ii) weekly village markets. Paddy sales were predominantly conducted through traders, with more than 70% of farmers delivering their produce directly to them. The remaining 30% of farmers sold their paddy at weekly village markets. In contrast, for other crops such as wheat, potatoes, vegetables, and jute, most farmers relied on weekly village markets as their primary selling platform.

Other marketing options, including government procurement agencies, hauler mills, and organized marketplaces, were entirely absent in the study area. The absence of these facilities limits farmers' ability to secure favourable prices and restricts their market access.

A high proportion of agricultural produce being marketed indicates a shift toward commercialized farming. The study found that a significant portion of the farm output was sold in markets at varying prices. Crops such as vegetables, potatoes, wheat, jute, paddy, and oilseeds were among the most market-oriented, with more than half of their total production being sold commercially. This trend suggests that the commercialization of agriculture has gained momentum among the sample farmers in the study area, reflecting a departure from traditional subsistence farming.

the findings highlight the significant infrastructural developments in agricultural transformation within Kamrup District. The availability of modern farm inputs, improved irrigation facilities, effective extension services, accessible agricultural finance, and evolving marketing practices all contribute to a more structured and commercialized agricultural landscape. However, challenges remain in the form of delayed government input distribution, financial barriers, and limited market infrastructure, which need to be addressed to ensure sustainable agricultural progress.

4. Conclusion

The discussions presented in this study indicate that the introduction of capital-intensive technology has led to only a partial transformation of agriculture among the farmers of Kamrup district in Assam. The reason behind this is that the farmers in the study area have not been able to fully integrate the high-yielding varieties (HYVs)-fertilizer-water technology into their farming practices. Although they have adopted improved varieties of seeds, a significant portion of the HYVs acreage is occupied primarily by rice. Crop diversification, while present, remains mostly limited to vegetables. Moreover, cropping intensity has remained relatively low, reflecting the incomplete adoption of new technologies. Several constraints hinder the widespread use of fertilizers, including the scarcity of input delivery mechanisms and the high cost

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of farm inputs. The inadequate supply of water further exacerbates these challenges, as irrigation facilities in the region are limited mainly to shallow tube well (STW) irrigation. Major and medium-scale irrigation facilities are almost nonexistent in the sample farms, preventing farmers from maximizing the benefits of new agricultural technologies. While village-level agricultural extension services have been somewhat effective, other essential infrastructures, such as agricultural credit systems and marketing facilities, remain significantly underdeveloped in the study areas.

Given these findings, it is imperative to focus on identifying and developing the necessary infrastructure required for the rapid transformation of traditional agriculture in the region. Among the most critical infrastructural requirements is the provision of assured irrigation facilities, which could significantly enhance the effectiveness of new agricultural technologies among farmers. Therefore, the establishment of additional medium and major irrigation facilities should be prioritized in government agricultural policies. Adequate and consistent water supply is essential for optimizing crop yields, ensuring sustainability, and encouraging farmers to invest in modern farming techniques. Without these irrigation facilities, the adoption of capital-intensive technologies will remain incomplete, and the full benefits of modern agricultural advancements will not be realized.

Another crucial area that requires urgent attention is the improvement of input delivery mechanisms. Farmers must have access to original, high-quality agricultural products, including seeds, fertilizers, and pesticides. The prevalence of duplicate farm inputs has had a detrimental impact on crop productivity, leading to mistrust among farmers regarding new varieties of crops. To address this issue, the government should implement measures to ensure the proper distribution of agricultural inputs. Establishing reliable input delivery systems would enable every farmer to procure genuine farm inputs at reasonable prices from nearby centers. Such measures would not only improve productivity but also increase farmers' confidence in adopting modern farming techniques.

Equally important is the role of rural credit institutions in facilitating agricultural transformation. These institutions must adopt a more proactive approach to supporting farmers, particularly in adopting progressive cultivation methods and new crop varieties. At present, the financial support provided by these institutions is inadequate, and many farmers struggle to secure loans due to complex formalities and high-interest rates. To address this challenge, rural credit institutions should expand their presence in remote agricultural areas and simplify the lending process. By reducing bureaucratic formalities to the bare minimum, these institutions can ensure that farmers, especially those from economically disadvantaged backgrounds, can access financial assistance easily. Additionally, interest rates on agricultural loans should be kept low, enabling even the poorest farmers to invest in better agricultural operations without falling into financial distress. By making credit more accessible, rural credit institutions can play a vital role in accelerating the adoption of capital-intensive technology and improving agricultural productivity.

Another key challenge that farmers face is the lack of adequate information to assess and mitigate risks associated with modern agricultural practices. While farmers are willing to take risks in pursuit of higher profits, they often lack the necessary information to make informed decisions. Addressing this issue requires a multifaceted approach. First, farmers should be provided with proper guidance and support in evaluating the risks associated with adopting new agricultural technologies. Second, there is a need to enhance farmers' access to market information, which can be achieved through the integration of information and communication technology (ICT) in the agricultural sector. By leveraging ICT, farmers can receive real-time updates on market conditions, demand trends, and pricing, enabling them to make more informed decisions. Third, efforts should be made to facilitate direct market access for farmers, reducing their dependence on intermediaries and improving their profit margins. Lastly, farmers should be equipped with the ability to store their produce adequately until it reaches the market. This would help them avoid distress sales and obtain better prices for their crops, thereby increasing their overall profitability.

The effectiveness of village-level agricultural extension services also needs to be enhanced. These services play a crucial role in bridging the knowledge gap between farmers and modern agricultural practices. However, the current extension services need to be more proactive and efficient. Extension workers should focus on training farmers in modern cultivation techniques before new technologies are introduced to them. This hands-on training approach would enable farmers to adopt the new methods more effectively and optimize their agricultural output. By improving the extension system, farmers can gain a better understanding of innovative agricultural practices, ultimately leading to positive changes in their farming behaviour.

Furthermore, integrating information technology into the agricultural sector in Assam could prove highly beneficial. If implemented effectively, IT solutions could provide farmers with end-to-end assistance, covering everything from land records management to input supply chains. Additionally, IT could help farmers stay informed about newly introduced seed varieties, cultivation methods, and market prices across different regions. This access to up-to-date information would enable farmers to make more strategic decisions regarding their agricultural operations. Moreover, the introduction of digital platforms could facilitate better coordination between farmers, input suppliers, and agricultural experts, thereby streamlining the entire agricultural ecosystem.

Another critical factor in ensuring the successful adoption of new agricultural technologies is the active participation of farmers in grassroots organizations and farmers' associations. At present, existing farmers' organizations and community groups have not played a significant role in agricultural development. To address this, there needs to be greater synergy between village-level agricultural extension workers and farmers' organizations. Organizations such as farm management

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committees and water users' associations should take the initiative to collaborate with agricultural authorities and seek information on available schemes and assistance programs. Likewise, government officials should engage more actively with farmers, providing clear and accessible explanations of government initiatives and their potential benefits. This two-way communication process would ensure that farmers are well-informed about the support available to them and encourage them to take advantage of these opportunities.

Ultimately, achieving agricultural transformation in Assam requires a coordinated effort among various stakeholders, including farmers, extension workers, credit institutions, and government agencies. Farmers must be more open to embracing new technologies, while government bodies must create an enabling environment by improving infrastructure, credit access, and input delivery systems. The success of capital-intensive technology in agriculture hinges on the availability of essential resources, including irrigation, financial support, market access, and reliable information. By addressing these key challenges, Assam can move towards a more progressive agricultural sector, benefiting not only farmers but also the broader rural economy.

In conclusion, the findings of this study emphasize the urgent need for targeted interventions to enhance agricultural productivity and sustainability in Kamrup district. By prioritizing the development of critical infrastructure, improving input supply chains, facilitating access to credit, leveraging information technology, and strengthening grassroots organizations, the agricultural sector in Assam can undergo a meaningful transformation. With concerted efforts from all stakeholders, capital-intensive technology can serve as a catalyst for rural development, improving livelihoods and ensuring food security in the region.

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