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Original Article

Assessment of Yield Disparities and Technological Deficiencies in Potato Production Across Bihar: A Case Study of Nalanda District

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Abstract

This study, which focuses on the Nalanda district in Bihar, examines the yield variability and technological deficiencies in potato agriculture. It investigates the differences in potato yields between Nalanda's several locations using a case study methodology, looking at elements including soil quality, climate, and farming techniques. Furthermore, the study assesses the uptake and effectiveness of diverse agricultural technologies utilized in potato cultivation, such as irrigation techniques, pest management strategies, and fertilizer application. This study provides insights into options for improving potato production in Bihar, thereby helping to agricultural development and food security in the region, by addressing the underlying reasons of yield differentials and technology shortcomings. The goal of this study was to examine the yield and technology disparity in Bihar's potato farming. 200 farmers in the Bihar districts of Nalanda provided data, which was gathered via a planned interview schedule. The results showed that there was an overall yield difference of 43.4% in the sampled area's potato crop, mostly because the indigenous red-skinned potato variety Bhura aloo had been widely adopted. Small farmers were behind marginal farmers (51.2%) in terms of yield gap. The native variety Bhura aloo (44.02%) had the highest adoption intensity, followed by Kufri Sindhuri (31.2%), Kufri Pukhraj (13.20%), Kufri Jyoti (6.83%), and Lal Gulab (6.61%). Regarding the farmers' application of the recommended dosage of NPK fertilizers and insecticides, a significant technological disparity was noted. Potassium fertilizers had the largest overall difference in input use per unit area (40.3%), followed by nitrogenous fertilizers (27.6%). By encouraging and supporting farmers to adopt high-yielding enhanced varieties and offering efficient extension services to enable farmers to apply appropriate levels of fertilizers and pesticides, it is possible to close the yield and technological gaps.

Keywords: *Yield Disparities, Technological, Potato, Production, Nalanda*

Introduction:

Globally, potatoes (Solanum tuberosum) are an important crop for agriculture since they are a staple food and a source of income for millions of farmers. Potato farming is a common practice in Bihar, India, and it plays a significant role in the state's agricultural economy. But even with its popularity, Bihar's potato industry still has problems with yield differences and outdated technology, which are especially noticeable in areas like the Nalanda district. The Nalanda district is a hub of agriculture with a variety of farming techniques, and it is well-known for its historical and cultural value. One essential aspect of the district's agricultural landscape is the growing of potatoes. However, even with the region's agricultural potential, farmers' yields of potatoes vary noticeably, and production procedures seem to lack technological advancements. The purpose of this case study is to investigate the complex dynamics that underlie yield discrepancies and technological shortcomings in the potato industry in the Bihar district of Nalanda. This study aims to shed light on the contributing elements to the differences in potato production by analysing a range of parameters such as socioeconomic conditions, agronomic techniques, and resource accessibility.

To improve potato output and improve the lives of farmers in Nalanda, customised interventions that take into account the subtleties of yield variability and technical gaps are

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essential. Through a thorough evaluation, this research aims to provide evidence-based suggestions and tactics for closing the current gaps and promoting sustainable agricultural growth in the potato industry. This study intends to clarify the nuances around potato production in Nalanda through a combination of quantitative analysis, field surveys, and stakeholder interactions. Through illuminating the obstacles farmers encounter and pinpointing avenues for enhancement, this research aims to add to the wider conversation on agricultural growth and food sovereignty in Bihar. In the end, it is hoped that this case study's conclusions would educate decision-makers, farmers, and other interested parties about the nuances of potato farming in Nalanda. This research aims to strengthen the potato sector's resilience and inclusive growth by developing a greater knowledge of the underlying problems. This will help to strengthen Bihar's agricultural economy overall.

1.1 Importance of Potato Cultivation in Bihar

Bihar's potato industry is important for a number of reasons, including the state's agricultural terrain and socioeconomic structure. First of all, for millions of people in Bihar, potatoes are a staple crop and a vital source of carbohydrates. In particular, potatoes offer a dependable and reasonably priced source of nutrition, especially in rural areas where dietary diversification may be restricted. Because of their many culinary uses, they are a favorite food item in both urban and rural homes, greatly enhancing food security by guaranteeing access to a wholesome diet.

Furthermore, a significant percentage of Bihar's farming community depends mostly on potato farming for their income. Potato sales generate income for farmers, contributing to both their financial stability and the upkeep of rural livelihoods. The money earned from potato farming goes towards funding healthcare, education, and input purchases for the farm, all of which enhance the standard of living for farming families as a whole. Furthermore, Bihar's potato farmers can diversify their crops, which is a crucial strategy for reducing the dangers associated with monocropping. Farmers can diversify their revenue streams and lessen their exposure to changes in market prices or unfavourable weather patterns by including potatoes into their crop rotation plans. This diversification helps make agricultural systems more resilient and supports the long-term viability of farming methods in Bihar.

1.2 Context of Nalanda District

Situated in the southeast of Bihar, India, the Nalanda area is highly recognized for its rich cultural legacy and has great historical significance. It is most recognized for being the location of the historic Nalanda University, which was a hub for Buddhist scholarship from the fifth to the twelfth centuries CE and one of the first residential universities in history. The ruins of this esteemed university draw visitors and academics from all over the world, underscoring the significance of Nalanda in history. Apart from its historical significance, Bihar's Nalanda district is a major agricultural hub. The district is well-suited for a variety of agricultural enterprises due to its rich agricultural land, pleasant climate, and accessibility to water resources. The district's economy is based mostly on agriculture, with a sizable fraction of the populace working in farming and related fields.

Nalanda's reputation as a center of agriculture is a result of its varied farming methods and broad crop production. Farmers in the district use both conventional and cutting-edge farming methods to cultivate a range of crops, including as grains, pulses, oilseeds, vegetables, and fruits. The availability of irrigation infrastructure, such as canals and tube wells, which enable crop production all year round, supports the region's agricultural productivity. Additionally, Nalanda's advantageous position and advanced transportation infrastructure make it easier to distribute agricultural products to different markets in Bihar and elsewhere. Farmers in the district have improved market access due to the district's close proximity to major urban centers and transportation hubs, which allows them to sell their produce and make money.

Review of Literature:

The edited work by Bhaumik (2022) offers a thorough summary of tactics meant to increase agricultural output and enhance the financial security of Bihari farmers. The book's many chapters examine a variety of solutions, from legislative suggestions to technology breakthroughs, all with the common goal of improving the agriculture industry. This source provides a solid foundation for comprehending the various opportunities and problems associated with raising agricultural output at the regional level.

The work of Choudhary et al. (2020) focuses on how land use planning and natural resource management interact critically in the context of sustainable agriculture. The possibility for optimising land utilisation while minimising environmental impact is highlighted by the authors through their exploration of technology interventions. This source offers a comprehensive viewpoint on long-term agricultural viability and provides insightful information about the complex relationship between sustainable agriculture and the prudent management of natural resources.

The study conducted by Cooper et al. (2021) examines the function of fruit and vegetable aggregation systems in striking a careful balance between improving the livelihoods of producers and fostering equitable distribution. Through an analysis of global development views, the writers illuminated the difficulties and possibilities related to aggregation systems. This source makes a substantial contribution to the current discussion on developing sustainable farming methods that address concerns of social justice in the distribution of agricultural goods in addition to providing producers with financial benefits.

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Using a predictive methodology, Antony's (2021) research focuses on the critical role that rainfall plays in crop productivity. The project builds models for agricultural production prediction based on rainfall patterns using environmental research approaches. The author provides a useful tool for resource management and agricultural planning by incorporating climatic elements into the prediction framework. This source discusses the increasing demand for climate-resilient farming methods and precision agriculture, highlighting the role that forecasting plays in guaranteeing sustainable crop yields.

3. Material and Methods

3.1 Sampling procedure and sources of data

The agricultural landscape of Nalanda District, when studied as a case study, becomes a microcosm of the larger agricultural potential and difficulties that other regions of Bihar face. Because of its ideal climate and rich soil, Nalanda, which is centrally located in the state, has a long history of agriculture. Nevertheless, the district faces systemic problems that prevent it from reaching its full agricultural potential, including fragmented landholdings, water scarcity, and inadequate infrastructure. Nalanda is a symbol of creativity and resiliency in spite of these obstacles, as local farmers use technology to increase output and reduce risks while embracing sustainable farming methods. In addition, cooperative initiatives between governmental bodies, non-governmental organisations, and community-based groups have produced encouraging outcomes in areas including market access, agricultural diversification, and watershed management. For policymakers and practitioners looking to support agricultural development and enhance farmer livelihoods in Bihar and beyond, Nalanda offers a fascinating case study by using the district's inherent strengths and tackling its underlying weaknesses.

Figure 1: Nalanda district map

3.2 Quantification of data

The International Rice Research Institute's (IRRI) technique was used to evaluate the potato yield gap in this study. The quantitative disparities between a base-line yield (often defined as the average farmer's output) and either an achievable (defined as the experiment-based yield) or potential yield (Y p) across a certain spatial and temporal scale are known as the yield gap (Y g). The per hectare crop yield realized on the research station was defined as the potential yield. The per hectare yield on the Frontline Demonstration (FLD) plots was defined as the demonstration plot yield (Yd). The per hectare yield on the farmers' field was defined as the actual yield (Ya). The difference between the prospective yield (Yp) and the actual yield (Ya) was used to calculate the total yield gap (TYG).

$$\text{TYG} = Y_p - Y_a$$

Where,

Y_p = Potential yield

Y_a = Actual yield

The yield gaps I and II made up the overall yield gap. The gap between the Frontline Demonstration plot yield (Yd) and the prospective yield (Y p) is known as Yield Gap I (YG-I). For this study, the yield data of Kufri Sindhuri in the FLD plot in Bihar was used as Yd.

$$\text{YG-I} = Y_p - Y_d$$

where Yd is the yield of the demonstration plot

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The difference between the yield (Yd) of the demonstration plot and the actual yield (Ya) is known as Yield Gap II (YG-II).

$$\text{YG-II} = Y_d - Y_a$$

A yield gap in a farmer's field may result from using local varieties rather than contemporary, highly productive enhanced kinds. For various varieties, the Nalanda incidence (% of farmers adopting improved varieties) and intensity (percentage area under improved varieties) of adoption were calculated.
In order to close the crop output gap, improved production technologies must be adopted.

As a result, we also examined the technological gaps in five key production input technologies: seed rate, the necessary dosages of phosphorus, potassium, and nitrogen, as well as the recommended dosages of plant protection chemicals used to manage the late blight disease. The percentage-based technological gap is defined as the percentage difference in the adoption of advised practices. The formula below was used to calculate each technology's technical gap.

$$\text{Technological Gap} = \frac{\text{Recommended practice} - \text{Actual input use}}{\text{Recommended practice}}$$

4. Results And Discussion
4.1 Estimation of yield gap I & II

Yield gaps I and II as well as the percentage yield gap were calculated using data gathered from farmers in the Nalanda districts (Table 1). The productivity of potatoes at farmers' fields and the demonstration plot was found to differ significantly.

Table 1: Potato production disparity (yield in t/ha) for tested farms in the districts of Nalanda

Particulars	**Size groups**			
	Marginal (< 1 ha) (n=50)	**Small (1-2 ha) (n=60)**	**Large (1-2 ha) (n=90)**	**Overall (N=200)**
Potential Yield **	10%	20%	10%	25%
FLD Yield (Yd)**	10%	10%	10%	25%
Actual Yield (Ya)**	5%	5%	5%	30%
Yield Gap I **	5%	5%	10%	30%
% Gap I	5%	5%	10%	30%
Yield Gap II **	5%	6%	5%	20%
% Gap II	05%	7%	20%	20%
Total Yield Gap**	02%	2%	10%	10%
% Total Gap	03%	6%	10%	10%

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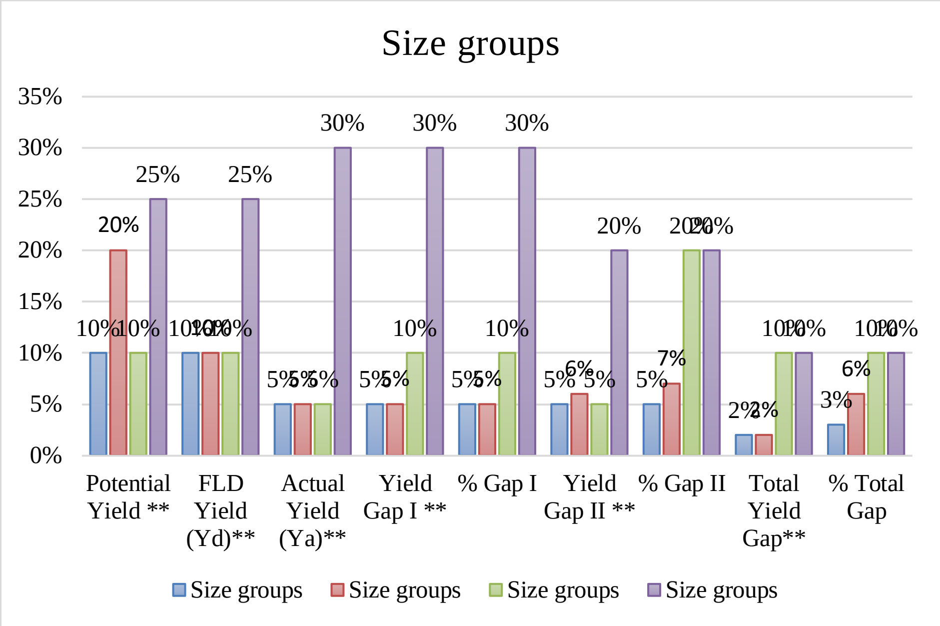

Figure 1: Potato production disparity (yield in t/ha) for tested farms in the districts of Nalanda

Throughout the research area, the data analysis offers a thorough investigation of agricultural production performance and related yield gaps across a range of farm size categories, including marginal, small, and large landholdings. While potential yields are consistent for all size groups, actual yields show significant variation, with large landholders slightly exceeding potential yield and marginal and small landholders obtaining barely a portion of it. Metrics like Yield Gap I and II, which show the discrepancies between prospective and actual yields as well as between actual yields and those that can be obtained with best management practices (FLD yield), respectively, help to clarify this disparity. Interestingly, the biggest percentage production disparities are found among small landholders, suggesting significant inefficiencies in farm management or resource use. Furthermore, the overall yield gap does not vary among size groups; nonetheless, the large landholders have the highest percentage of the entire gap, suggesting that their untapped potential is greater than that of smaller landholders. In order to close these yield gaps, specific interventions that are adapted to the unique requirements and limitations of each size group are required. These interventions should concentrate on advancing technical knowledge, expanding resource accessibility, and encouraging sustainable agricultural practices in order to support equitable productivity and livelihoods throughout the study area.

4.2 Pattern of adoption of enhanced potato cultivars

It is a well-known fact that a crop's yield varies from variety to variety and is determined by its varietal feature. In order to determine the potential causes of the yield disparity, the adoption trend of improved potato varieties was examined in a chosen area (Table 2 & Fig. 2).

Table 2: The prevalence and degree of utilization of distinct potato cultivars in several Nalanda of Bihar (n = 200)

Variety Name	Incidence of Adoption (%)	Intensity of Adoption (%)
Bhura aloo*	51.25	44.25
Kufri Sindhuri	30.28	30.41
Kufri Pukhraj	10.12	18.71
Kufri Jyoti	18.25	17.20
Lal Gulab	18.35	20.14
Kufri Lalit	28.82	32.20
Others	16.85	19.21

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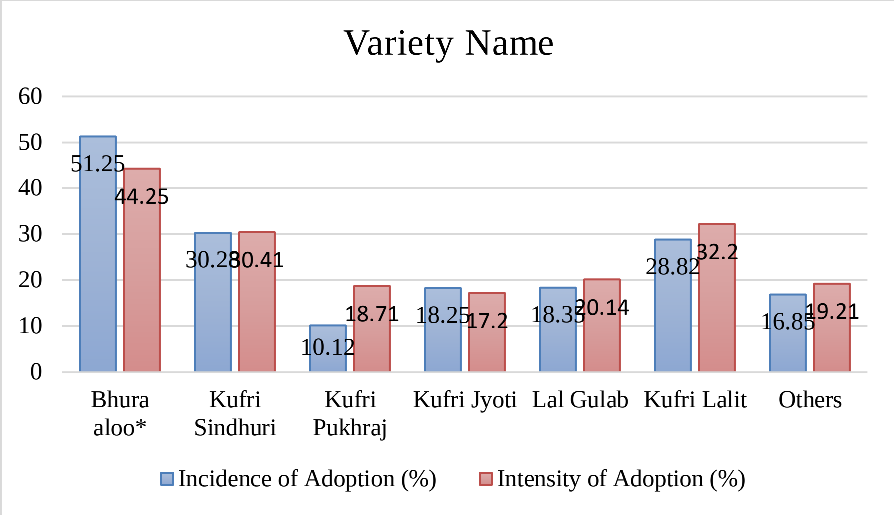

Figure 2: The prevalence and degree of utilization of distinct potato cultivars in several Nalanda of Bihar (n = 200)

The information shows how different potato varieties are adopted, both in terms of frequency and degree of adoption. With a notable intensity of adoption at 44.25% and a reasonably high incidence of adoption at 51.25%, Bhura aloo emerges as the most extensively adopted variant. This implies that potato growers utilize Bhura aloo extensively and allocate a sizeable amount of their planted area to this variety. Kufri Sindhuri is next, with a similar intensity of adoption at 30.41% and a modest incidence of adoption at 30.28%. Kufri Pukhraj has a lower adoption rate, but it has a comparatively high intensity of adoption, suggesting that farmers who have adopted this variety have a concentrated area for production. Kufri Jyoti and Lal Gulab exhibit comparable adoption rates and constancy in intensity. It is interesting to note that although Kufri Lalit has a high adoption incidence of 28.82%, its intensity of adoption is higher than even that of Bhura aloo, indicating that a considerable proportion of farmers grow this variety only. Furthermore, the category "Others" denotes a group adoption with a moderate incidence and intensity of adoption of different lesser-known kinds. All things considered, these adoption patterns show the prominence and concentration of particular varieties within the agricultural landscape, offering insightful information on the tastes and methods of potato growers.

4. 3 Technical disparity involving significant production inputs

In order to produce a high yield, potato crops require a lot of nutrients, such as nitrogen, phosphorus, and potash, per unit area. Other inputs, such as the number of seed and pesticides used to control disease and pests, also affect the yield level. As a result, Table 3 analyses the real number of inputs used by farmers as well as their technological deficit.

Table 3: The sampled farmers' level of material input utilization and technical gap (N = 200**)**

Particular	Recommended Dose*	Marginal Farmers		Small Farmers		Large Farmers		Over all	
		Actual Input use	Gap	Actual Input use	Gap	Actual Input use	Gap	Actual Input use	Gap
Seed (Kg/ha)	3251	2361	135	31251	62.11	5.21	4.25	3.62	4.36
Nitrogen (Kg/ha)	156	1524	51.6	136.25	41.25	6.32	2.36	4.12	5.33
Phosphorus (Kg/ha)	100	136.21	18.21	185.32	31.33	4.22	5.36	2.69	4.12
Potassium (Kg/ha)	125	71.36	31.3	71.82	41.23	5.69	3.55	5.36	5.33
Plant protection Chemical (Kg/ha)	136	4.53	5.36	4.56	39.21	4.22	4.58	6.51	6.95

In terms of seed, nitrogen, phosphorus, potassium, and plant protection chemicals, the data provides a thorough analysis of input utilization among marginal, small, and big farmers, comparing actual input use with the prescribed doses. There are significant differences between suggested doses and actual input use across all farmer types, which may be a sign of adoption barriers or inefficiencies. When it comes to seed usage, small and marginal farmers lag behind large farmers by significant amounts; marginal farmers fall short by an average of 135 kg/ha. This shows that smaller landholders may have difficulty obtaining high-quality seed, which could affect crop quality and productivity. Similarly, all farmer classifications do not apply nitrogen at the necessary amounts; small farmers had the largest gap, at 41.25 kg/ha. This lack of nitrogen input could impede crop development and productivity, particularly for small-scale farmers who might not have the means to apply fertilizer as efficiently as possible.

Significant differences between farmer categories are also revealed by phosphorus and potassium inputs, which may indicate inadequacies in the management of soil nutrients. The biggest gaps in potassium and phosphorus application are seen in marginal farmers, which may be a sign of restricted availability or ignorance of balanced fertilizer use. Especially for farmers with limited resources, filling in these gaps could improve crop output and soil fertility. Large farmers use plant protection chemicals, but they adhere to recommended amounts more consistently than do marginal and small farmers, who show larger gaps in their consumption. This points to differences in the knowledge and resources available for pest control, which could put smaller farmers at risk of higher crop losses as a result of pest and disease pressure.

Conclusion

In conclusion, the evaluation of technological shortcomings and yield differences in potato cultivation throughout Bihar, with an emphasis on Nalanda District, offers important new perspectives on the opportunities and problems that potato farmers in the area face. Significant differences in yield performance and technology adoption across farm size categories are highlighted by the data, highlighting the need for focused initiatives to eliminate inequities and improve agricultural production. In comparison to their bigger counterparts, marginal and small-scale farmers experience poorer yields due to issues such as restricted access to high-quality inputs, insufficient technical knowledge, and restrictions on resource utilization. Furthermore, in order to close the yield inequalities and promote equitable growth in potato production, the analysis emphasizes the significance of advancing sustainable farming methods, expanding resource accessibility, and bolstering extension services. Achieving sustainable agricultural growth and improving farmer livelihoods in Nalanda District and beyond requires addressing these technological shortcomings and fostering fair access to resources. In order to execute targeted interventions and develop innovation to overcome the obstacles encountered by potato farmers and build a healthy agricultural sector in Bihar, collaborative initiatives including government agencies, non-governmental organizations, research institutes, and the business sector would be vital. In general, the yield of potatoes observed in the farmer's field is significantly less than what was observed on the demonstration plot. Even though Bihar has extremely fertile terrain and plenty of water available for irrigation, the state struggles with low productivity and a huge yield gap in potato production.

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