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Soil health status under continuous rice-maize cropping system in eastern sub-Himalayan region of India due to nutritional management practice by farmers

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Abstract
The Rice-Maize system (RMS) is emerging as a profitable cropping system in Eastern India, particularly in the Sub-Himalayan region of West Bengal. Although RMS has high productivity potential and could replace traditional systems like Rice-Wheat or Rice-Jute, issues such as poor yield due to low fertilizer application, delayed/early sowing, and environmental stress remain significant challenges for farmers. R-M system exists in all climates ranging from tropical to sub-tropical to warm temperate. Maize can be grown in all three major cropping seasons of India, providing a flexible option to support diversification of existing cereal-based cropping systems (Timsina *et al*., 2010). The R-M System is characterized by high nutrient removal from the soil, particularly driven by higher yield of maize. However, cultivating two cereal crops in rapid sequence may leads to decline in soil fertility resulting in yield reduction in both crops. The continuous nutrient depletion is a major threat to soil health. This nutrient depletion may be caused by various factors. Among them improper crop management practices by farmers are the leading cause. This survey was conducted to study the management practices followed by farmers and current soil nutritional status of R-M system.

Keywords: *Rice Maize System*, soil nutrition depletion, soil nutritional status

Introduction

Rice, wheat and maize are major cereals contributing to food security and income in India. Rice being a staple food in Eastern India, cropping system in this region typically include monsoon (aman) rice (*Oryza sativa* L.) during rainy *kharif* season, followed by a second rice (boro) crop (R-R system) or jute (*Corchorus* sp.) in areas where irrigation water is in ample supply. Where water is insufficient, maize (*Zea mays* L.), wheat (*Triticum aestivum)*, potato (*Solanum tuberosum*), or other crops are grown instead of *boro* rice in successive season. In Eastern Sub-Himalayan region of India, rice-jute (R-J) system is the most predominant among the rice-based cropping systems, but slowly R-J system is replaced by the Rice-Maize (R-M) system as it is emerging as a profitable among the other rice-based cropping systems (Ali *et al*., 2009) [1]. R-M system exists in all climates ranging from tropical to sub-tropical to warm temperate. Maize can be grown in all three major cropping seasons of India, providing a flexible option to support diversification of existing cereal-based cropping systems (Timsina *et al*., 2010) [9].

The R-M System is characterized by high nutrient removal from the soil, particularly driven by higher yield of maize. Using several data sets from South and Southeast Asia, Buresh *et al*. (2010) [3] reported that to produce 1 tonne grain yield of rice 14.6 kg N, 2.7 kg P and 15.9 kg K would be needed, based on 60-70% of the yield potential. A similar study by Setiyono *et al.* (2010) [7] estimated that 16.4 kg N, 2.3 kg P and 15.9 kg K would be required to produce 1 tonne of maize grain. Assuming 5 t ha^{-1} of rice yield and 9 t ha^{-1} of maize yield, R-M system will remove around 220 kg N ha^{-1}, when all the residues are removed from the field.

The demand of fertilizer is strongly influenced by the preceding crop and amount of fertilizer applied to them. Cereals like rice and maize demand sound and effective nutrient management for sustainable productivity. A study in Punjab and Haryana by Government of India in 1997 found that there is a decline in soil organic carbon content of soils in continuous cereals based cropping systems such as rice-wheat, rice-rice and rice-maize, etc. Among the major nutrients, Nitrogen is the most crucial in yield realization of rice and maize. In India, 67% of rice growing areas have shown a shortage of adequate nitrogen in soil and continuous cereals cropping system has becomes a major consumer of fertilizer nitrogen. Further the fertilizer use efficiency of nitrogenous fertilizer is quite low, seldom touches 40%, which has been another cause of worry and challenge to the farmers. Nutrient deficiencies in soil inherently cause reduced fertilizer effectiveness, lower crop yields, and decreased profits (Tiwari, 2002) [10]. This condition also contributes to the continued depletion of the scarcest nutrients in the soil. When a nutrient falls to its critical threshold, crop yields significantly decline, even with the application of large amounts of other nutrients (PPIC, 2000) [6]. Now a days, fertilizer cost and concern for sustainable soil productivity and agro-ecological stability in relation to chemical fertilizer use have emerged as important problem in agriculture sector.

Sandy and sandy loam soils which have low water holding capacity encourage leaching loss of valuable N fertilizers. Nitrogen leaching threatens ground water contamination with nitrate which is dangerous for both environmentally and from human health point of view. N management in system should reduce losses through denitrification, volatilization and leaching by providing different sources of nitrogen. In this region, inadequate use of N fertilizer failed to provide the N demand of the system but improper application method leads to loss of N fertilizer from the root zone due to climatic and edaphic factors.

To understand the soil N status of this region a baseline survey was conducted. Baseline survey is prepared for monitoring and evaluation process to define the impact of a project. It helps to determine main areas for project by giving data on what require immediate attention for measuring the success of a project. The survey conducted on questionnaire basis to evaluate the soil nutritional status, Rice-Maize system productivity and its sustainability in Eastern Sub-Himalayan region of India.

It was observed that several studies on the combined nutrient management on different parameters including crop yield and nutrient use efficiency are available for conventionally grown R-W system, but such studies are scarce in literature about effectiveness of different sources the N application on nitrogen availability and accumulation in R-M system. Evaluating the traditionally grown rice and maize in eastern Sub-Himalayan region of India is of immense importance to understand their N balance in the system.

Materials and Methods:

A baseline survey was conducted to determine the nutritional status of the soil in R-M system in Sub-Himalayan region of West Bengal. The study area lies from 26º 19' N and 88º23' E to 26º54'N and 89º51' E, area of Cooch Behar district of West Bengal. A questionnaire prepared to get the basic information regarding management practices followed in R-M system from the 30 farmers who had followed R-M system for at least 5 years. Farmer's basic information on Landholding details, Land Characteristics, cropping system practiced by farmers, Total area under Rice-Maize cropping system, Last 5 years cultivation details (date) for rice and maize, Package of practices followed by the farmers in rice and maize, harvesting operation details followed by the farmers in rice and maize.

From the 30 responding farmers R-M system fields soil samples were collected form 0-15 cm depth to evaluate the current soil nutritional status. Collected soil samples were shade dried and grided with mortar and pestle, passed through a 2 mm sieve. After that collected soil samples were ready to further laboratory analysis. Soil pH was determined based on Barua and Barthakur (1997) and Soil EC was estimated following the protocol of Jackson (1973) [5]. Estimation of soil organic carbon was conducted by chromic acid method established by Walkley and Black, 1934 [11]. Quantification of available nitrogen by alkali permanganate method by Subbhiah and Asija, 1956.

Results and Discussion

This section presents and interprets the findings related to land utilization, biophysical farm characteristics, and fertilizer management behaviour among the 30 sampled farmers.

Land Holding and Farm Characteristics

The socio-demographic profile of the respondents indicates that the farming community is composed exclusively of small (40.0%), semi-medium (50.0%), and medium-scale (10.0%) landholders (Table 1). The mean total landholding was 9.3 bigha, distributed across varied topographies. On average, farmers managed 5.7 bigha of medium land and 5.7 bigha of lowland, with a smaller portion of 2.6 bigha classified as upland. The average distance from the homestead to the land was 396.7 meters, and to a water source was 132 meters.

Table 1: Land Utilization and Holding Characteristics (n=30)

Land Utilization pattern (n= 30)		Mean (bigha)	
Slope status of land	Upland	2.636364	
	Medium	5.684211	
	Lowland	5.68	
	Total	9.3	
Distance from Home (m)	Land	396.6667	
	Water source	132	
		f (n=30)	**%**
Land Holding	Marginal (< 1 ha)	0	0
	Small (1 to 2 ha)	12	40.00
	Semi-medium (2 to 4 ha)	15	50.00
	Medium (4 to 10 ha)	3	10.00
	Large (> 10 ha)	0	0
Source of Irrigation	Shallow	27	90.00
	Pond	3	10.00

Biophysical Resources: Soil, Irrigation, and Fertility

The biophysical conditions of the farms present a distinct set of opportunities and challenges. As shown in Table 2, there is an overwhelming reliance on shallow wells (90.0%) for irrigation.

The predominant soil type is sandy loam (63.3%), with smaller areas of loam (16.7%) and clay (20.0%). The majority of the soil was classified as deep (50.0%) or very deep (33.3%), a favourable condition that allows for extensive root development. In terms of perceived fertility, two-thirds of the farmers rated their soil as good (66.7%), while one-third rated it as poor (33.3%).

Table 2: Biophysical Characteristics of Farms (n=30)

Parameter		f (n=30)	%
Soil type	Loam	5	16.66
	Sandy Loam	19	63.33
	Clay Loam	0	0
	Clay	6	20.00
Depth of Soil	Shallow	5	16.66
	Deep	15	50.00
	Very Deep	10	33.33
Soil fertility	Very poor	0	0
	Poor	10	33.33
	Good	20	66.66
	Very good	0	0

Soil Physicochemical Properties

Laboratory analysis of soil samples provides a quantitative basis for the farmers' perceptions of fertility (Table 3). The mean soil pH was 5.72, indicating moderately acidic conditions. The mean Electrical Conductivity (EC) was very low at 0.13 dS/m, confirming the soil is non-saline and free from salt-induced stress.

A critical finding is the low mean Organic Carbon (OC) content of 0.52% which indicates poor soil health status. Furthermore, the mean Available Nitrogen (N) was 238.85 kg/ha, a level typically classified as low to medium.

Table 3: Mean Soil Physicochemical Properties (n=30)

	Parameters	Mean (n=30)
Soil properties	pH	5.716667
	EC (dS/m)	0.128333
	OC (%)	0.52
	Available N (kg/ha)	238.848

Fertilizer Using Behaviour: A Conflict Between Knowledge and Practice

The survey on fertilizer using behaviour reveals a significant disconnect between farmers' cognitive understanding and their practical actions, primarily driven by economic constraints (Table 4).

Cognitive and Economic Factors: Farmers displayed a high level of situational awareness. The highest mean score was for the statement, "I think that lowland fields require less fertilizer due to nutrient runoff from higher areas" (4.62 on a 5-point scale). Farmers also strongly agreed that excessive fertilizer use is harmful in the long run (4.25).

However, this knowledge is powerfully counteracted by economic realities. The strongest agreement in the entire survey was with the statement, "I reduce the amount of fertilizer I use because the prices are too high" (4.53). This is reinforced by high agreement with skipping applications due to lack of cash (4.12) and the desire to apply more if it were affordable (3.98). This evidence strongly suggests that economic barriers are the dominant factor dictating fertilizer application rates, overriding agronomic considerations.

Behavioural Patterns: Farmers do not adhere to a systematic fertilization plan, as indicated by the low score for following a fixed schedule (2.66). Conversely, they actively apply their knowledge where possible, indicated by the high score for changing usage based on land slope (4.15). Crucially, farmers self-report that they "often under-apply fertilizer compared to the recommended dose" (3.50).

Table 4: Mean score of Fertilizer Using Behaviour (n=30)

Fertilizer Using Behaviour		Mean (n=30)
Cognitive Factors	I am well-informed about the types of fertilizers suitable for my crops.	3.66
	I believe that excessive use of fertilizer harms the soil in the long run.	4.25
	I think that lowland fields require less fertilizer due to nutrient runoff from higher areas.	4.62
Economic / Practical Barriers	I reduce the amount of fertilizer I use because the prices are too high.	4.53
	I often have to skip fertilizer application due to lack of cash or credit availability.	4.12
	I would apply more fertilizer if I could afford to buy more.	3.98
Behavioural Patterns	I follow a fixed fertilizer schedule for each cropping season.	2.66
	I often under-apply fertilizer compared to the recommended dose.	3.50
	I change fertilizer usage based on the location and slope of the land.	4.15

Package of practices followed by farmers in Rice field

Land Preparation and Crop Establishment

The results indicate a high degree of mechanization in land preparation, with a vast majority of farmers (83.33%) utilizing tractors for an average of three ploughings per season. For crop establishment, all respondents exclusively used the wet-bedded nursery system and the transplanting method of sowing. However, a significant dichotomy was observed in the transplanting operation itself: while 56.66% of farmers still perform it manually, a substantial portion (43.33%) has adopted mechanical transplanters.

Nutrient and Weed Management

Nutrient management was primarily based on inorganic fertilizers, with an average application per bigha of Urea (10.16 kg), MOP (4.45 kg), and the complex fertilizer 10:26:26 (11.17 kg). This translated to a total nutrient application of 40.46 kg/ha N, 20.15 kg/ha P_2O_5, and 40.10 kg/ha K_2O. The use of organic manure was notably negligible at just 1.16 kg/bigha. For weed control, farmers employed an integrated approach, with all respondents practicing hand weeding, which was supplemented by the application of chemical herbicides by a large majority (86.66%).

Harvesting and Post-Harvest Operations

Harvesting remains a largely manual activity (90%), with minimal use of paddy harvesters (10%). Conversely, threshing is fully mechanized, with all respondents using power threshers. In post-harvest processing, parboiling was a common practice by all. The management of crop residue was also a key finding; rice straw was overwhelmingly utilized as livestock fodder (90%) and for sale (97%), indicating its high economic value.

Yield, Grain Quality, and Farmer Perception

The described practices resulted in a mean grain yield of 3.52 t/ha. The harvested grain was predominantly of medium (50%) followed by bold (43.33%) size and uniformly white (100%). Despite the acceptable yield, the farmer-perceived taste of the rice was relatively low, with a mean score of only 2.62 out of 5.

Table 4: Details of Package of practices followed by farmer in Rice field (n=30)

Package of Practices related to Rice			
Land preparation		**Mean (n=30)**	
	Number of Ploughing	3.03~3	
Usage of machinery/Implements		**f (n=30)**	**%**
	Power tiller	5	16.66
	Tractor	25	83.33
	Wooden Plough	0	0
Nursery type	Dappog	0	0
	Wet bedded	30	100
	Dry bedded	0	0
Usage of new tech.	Manually	17	56.66
	Transplanter	13	43.33
	Other if nay	0	0
Nursery Management		**Mean (n=30)**	
	Seed rate (kg)	3.00	
	Spacing (sq. cm)	8 x10	
Usage of Fertilizer (kg/bigha)	Urea	10.16	
	DAP	0.00	
	MOP	4.45	
	10:26:26	11.17	
	Manure	1.16	
Total N applied (kg/ha)		40.46	
Total P_2O_5 applied (kg/ha)		20.15	
Total K_2O applied (kg/ha)		40.10	
Usage of Agro-Chemicals (ml/bigha)		18.00	
		60.00	
Method of Sowing		**f (n=30)**	**%**
	Broadcasting	0	0
	Transplanting	30	100
	SRI	0	0
Intercultural operation		**f (n=30)**	**%**
Weeding	Hand weeding	30	100
	Cono-weeder	0	0
	Mulching	0	0
	others If any (Chemical)	26	86.66
Harvesting	Paddy harvester	3	10.00
	Manually	27	90.00
	Other if Any	0	0
Stubble height (in Inch)	Mean height	5.965517241	
		f (n=30)	**%**
Threshing	Manually	0	0
	Power thresher	30	100
	other if Any	0	0
Yield (t/ha)	Mean	3.517333	
Taste (out of 5)	Mean	2.62	
Grain properties		**f (n=30)**	**%**
Size	Bold	13	43.33
	Medium	15	50.00
	Slender	2	06.00
Colour	Yellow	0	0
	Black	0	0
	Reddish	0	0
	White	30	100
Post-harvest management		**f (n=30)**	**%**
Processing	Parboiling	30	100
	Polishing	0	0
	other if Any	0	0
Usage of Straw	Shedding	0	0
	Mushroom pit	1	3.333333333
	Fodder	27	90.00
	Sale	29	96.66666667

Package of practices followed by farmers in Maize field

Land Preparation and Crop Establishment

Land preparation for maize is highly mechanized, with 73.33% of farmers using tractors for an average of 2.2 ploughings. A notable finding is the adoption of zero tillage by 26.66% of the respondents, indicating a move towards conservation agriculture practices. Crop establishment was uniformly modern and precise as all farmers practiced line sowing with a standardized spacing of 60 x 20 cm and used a seed rate of 2.22 kg/bigha.

Nutrient and Weed Management

The nutrient application for maize was substantially higher than for rice. On average, farmers applied a total of 110.03 kg/ha of Nitrogen (N), 61.55 kg/ha of P_2O_5, and 70.55 kg/ha of K_2O. This was achieved through a combination of Urea, SSP, MOP, and complex fertilizers. Manure application (5.95 kg/bigha) was also higher compared to rice. Weed management was dominated by chemical control, with all respondents using the herbicide Atrazine. This was supplemented by mechanical weeding (43.33%) and earthing up with a spade (73.33%), while manual hand weeding was minimal (26.66%).

Harvesting, Threshing, and Residue Management

A familiar pattern of selective mechanization was observed. Harvesting was conducted entirely manually, while threshing was fully mechanized, with all farmers using a power separator. A critical finding was in residue management: all crop residue (stover) was left in the field. While a large portion (43.33%) was simply discarded, a majority (56.66%) incorporated the stover back into the soil.

Yield and Grain Quality

The intensive management practices resulted in a high mean yield of 6.99 t/ha. The grain produced was uniformly of a bold size and golden yellow in colour, as reported by all respondents. Similar to rice, the farmer-perceived taste score was low, at 2.40 out of 5.

Table 5: Details of Package of practices followed by farmer in Maize field (n=30)

Package of Practices related to Maize			
Land preparation		**Mean (n=30)**	
	Number of Ploughing	2.20	
Usage of machinery/Implements		**f (n=30)**	**%**
	Power tiller	0	0
	Tractor	22	73.33
	Wooden Plough	0	0
	None	0	0
Usage of new tech.	Manually	0	0
	Zero tiller	8	26.66
	Other if nay	0	0
Nursery Management		**Mean (n=30)**	
	Seed rate (kg/bigha)	2.22	
	Spacing (sq. cm)	60 x 20	
Usage of Fertilizer (kg/bigha)	Urea	30.54	
	SSP	30.00	
	MOP	19.33	
	10:26:26	18.09	
	Manure	5.95	
Total N applied (kg/ha)		110.03	
Total P2O5 applied (kg/ha)		61.55	
Total K2O applied (kg/ha)		70.55	
Usage of Agro-Chemicals (gm/litre)	Atrazine	2.50	
	If any	0.00	
Method of Sowing		**f (n=30)**	**%**
	Broadcasting	0	0
	Line sowing	30	100
	Others if Any	0	0
Intercultural operation		**f (n=30)**	**%**
Weeding	Hand weeding	8	26.66
	Weeder	13	43.33
	Mulching	0	0
	others If any (Chemical)	30	100
Earthing up	Manually	0	0
	Spade	22	73.33
	Other if Any	0	0
Harvesting	Harvester	0	0
	Manually	30	100
	Other if Any	0	0
Residue remain	Fully	30	100
	Partially	0	0
	None	0	0
Threshing	Manually	0	0
	Power separator	30	100
	other if Any	0	0
Yield (t/ha)	Mean	6.99	
Taste (out of 5)	Mean	2.40	
Grain properties		**f (n=30)**	**%**
Size	Bold	30	100

	Medium	0	0
	Long	0	0
Colour	Yellow	0	0
	Golden Yellow	30	100
	Reddish	0	0
	White	0	0
Post-harvest management		**f (n=30)**	**%**
Usage of Stover	Partial Incorporated	9	30.00
	Fully Incorporated	8	26.66
	Fodder	0	0
	Discarded	13	43.33

Temporal Trend of Nitrogen Application and Yield in the Rice-Maize System

The temporal trends of nitrogen (N) application and the corresponding crop yields for both maize and rice were analysed over a five-year period from 2014 to 2018. The data reveals distinct patterns of input intensification and crop response, highlighting a growing disparity in the productivity and nutrient use efficiency of the two crops within the system.

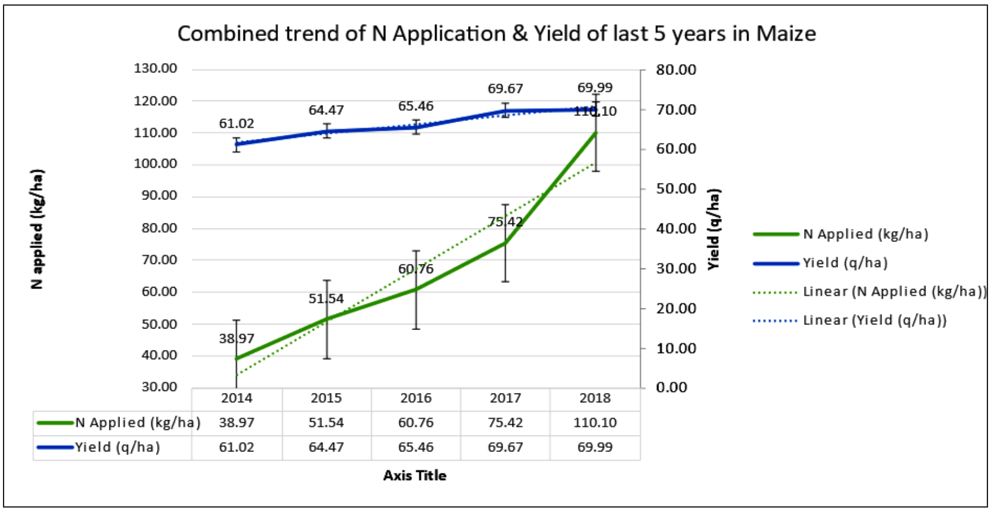

Fig 1: Trend Analysis for Maize

The N application for maize demonstrated a steep and consistent upward trend over the five-year period (Figure 1). The mean N application rate rose dramatically from 38.97 kg/ha in 2014 to 110.16 kg/ha in 2018, representing an increase of approximately 180%. This aggressive intensification of N use is confirmed by the steep positive slope of its linear trendline.

Correspondingly, the mean maize yield also showed a positive trend, increasing from 61.02 q/ha in 2014 to a peak of 69.99 q/ha in 2018. However, the rate of yield increase was not proportional to the rate of N application increase. A critical observation is the evidence of diminishing returns on nitrogen investment, particularly in the final year. From 2017 to 2018, N application increased by over 33 kg/ha (from 75.42 to 109.16 kg/ha), but this substantial input resulted in a negligible yield increase of only 0.32 q/ha (from 69.67 to 69.99 q/ha). The yield appears to be plateauing, suggesting that the crop is approaching its maximum potential under the current management and environmental conditions, and further increases in N application are becoming highly inefficient.

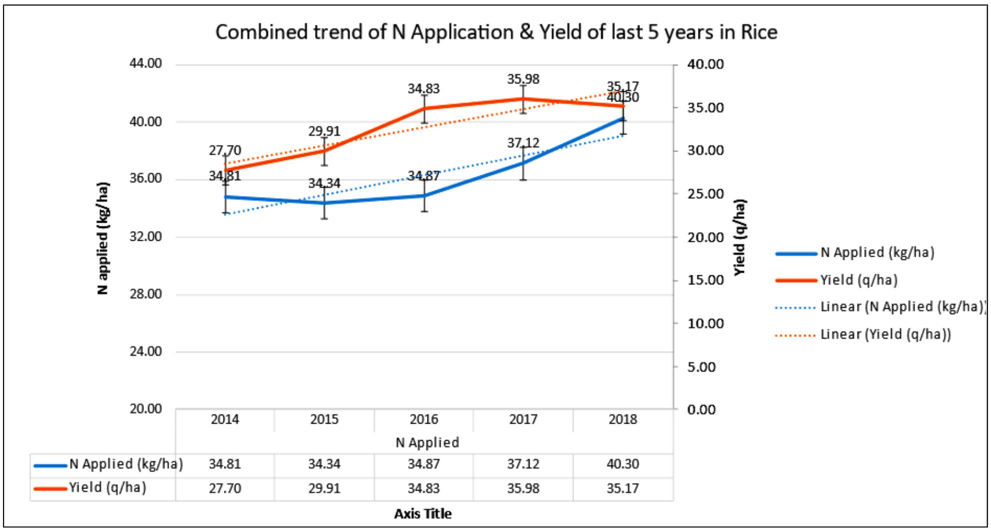

Fig 2: Trend Analysis for Rice

In contrast to maize, the trends for rice present a more complex and concerning picture (Figure 2). The application of nitrogen for rice showed a gradual but steady increase, rising from 34.81 kg/ha in 2014 to 40.30 kg/ha in 2018.

The yield of rice initially responded positively to the modest increases in N application, climbing from 27.70 q/ha in 2014 to a peak of 35.98 q/ha in 2017. However, a significant and critical divergence occurred in 2018. Despite the N application rate being the highest in the five-year period (40.30 kg/ha), the average yield reduced to 35.17 q/ha. This indicates that not only was the additional nitrogen ineffective, but the system may have crossed a threshold where increased N application under the prevailing conditions had a neutral or even reversal impact on grain yield. While the overall linear trendline for yield remains positive due to the gains from 2014-2017, the data from the final year signals an emerging problem of nutrient inefficiency and a potential decline in the performance of the rice crop.

Discussion

The analysis of the Rice-Maize cropping system, grounded in both farmer practices and five-year trend data, reveals a high-intensity yet ecologically unsustainable production model that is steadily deteriorating. While the system may appear economically rational due to its focus on maximizing maize yield, it is fundamentally flawed due to a profound management imbalance that depletes soil resources and undermines long-term sustainability. At the heart of the issue is a management approach that prioritizes maize as the primary crop and treats soil as an inexhaustible resource, manifesting in two critical and interlinked problems. First, the system suffers from an imbalanced nutrient budget where maize, managed as a high-extraction crop, receives substantial nutrient inputs (110-60-70 kg/ha NPK) to sustain yields close to 7 t/ha, whereas the succeeding rice crop is supplied with a sub-optimal dose (40-20-40 kg/ha NPK) that not only fails to meet its own nutritional requirements but also neglects to restore the nutrients extracted by maize, resulting in a chronic, net-negative nutrient balance that accelerates soil degradation. Second, the situation is worsened by the removal of nearly all rice straw (with 97% sold and 90% used as fodder), leading to an annual loss of organic carbon and essential nutrients- especially potassium - in a context where the soil's baseline organic carbon is already alarmingly low (0.52%). Although a slight compensatory practice exists in the form of maize stover incorporation by 57% of farmers, it is inadequate to offset the impacts of intensive tillage and near-total residue removal, which together drive a steady decline in soil health. The five-year trend data illustrates this degradation vividly: maize yield, despite a 180% increase in nitrogen application over the period, has plateaued, with 2017-2018 data showing a 45% rise in nitrogen input yielding less than 0.5% gain highlighting that nitrogen is no longer the limiting factor, and that soil health, rather than inputs, has become the primary constraint. Simultaneously, rice yields show an even more concerning trend, peaking in 2017 and then declining in 2018 despite the highest nitrogen application, indicating not just diminishing returns but actual soil exhaustion, where the soil overexploited by maize and deprived of organic matter can no longer convert even modest inputs into grain yield. This dual trajectory confirms the existence of a vicious cycle: the relentless drive for high maize yields through escalating inputs erodes soil health, which in turn demands more fertilizer just to maintain maize yields while further weakening rice productivity, creating a downward spiral of rising costs and stagnating or declining returns. Compounding this issue, low taste scores for both crops may reflect qualitative nutrient imbalances within the grain, offering further evidence of systemic stress. Thus, the system, as currently managed, is not only economically and ecologically inefficient but also unsustainable, calling for urgent intervention to restore soil health and rebalance nutrient management across the cropping cycle.

In conclusion, the Rice-Maize system, in its current form, is operating on borrowed time. The yield plateau in maize and the yield decline in rice are unambiguous signals that a fundamental shift from a purely N-centric strategy to an integrated soil health approach is an economic and ecological necessity. To reverse this trend and ensure long-term viability, management must evolve to include the partial re-incorporation of rice straw, the use of cover crops, and a more balanced, soil-test-based fertilizer regimen for both crops in the rotation. Without these changes, the system is on a quantified path toward long-term productivity collapse.

References

1. Ali MY, Waddington SR, Timsina J, Hudson D, Dixon J. Maize-rice cropping systems in Bangladesh: status and research needs. J Agric Sci Technol. 2009;3:35-53.
2. Baruah TC, Barthakur HP. A text book of soil analysis. New Delhi: Vikas publishing house Pvt., Ltd.; 1997.
3. Buresh RJ, Pampolino MF, Witt C. Field-specific potassium and phosphorus balances and fertilizer requirements for irrigated rice-based cropping systems. Plant Soil. 2010;335:35-64.
4. Dwivedi BS, Shukla AK, Singh VK, Yadav RL. Results of participatory diagnosis of constraints and opportunities-based trials from the state of Uttar Pradesh. In: Rao AS, Srivastava S, editors. Development of Farmers' Resource-based Integrated Plant Nutrient Supply Systems: Experience of a FAO-ICAR-IFFCO Collaborative Project and AICRP on Soil Test Crop Response Correlation. Bhopal, India: Indian Institute of Soil Science; 2001. p. 50-75.
5. Jackson ML. Soil chemical analysis. New Delhi, India: Prentice Hall of India Pvt. Ltd.; 1973. p. 485.
6. PPIC (Potash and Phosphate Institute of Canada). Balanced fertilizer use for sustainable agriculture in India. Gurgaon, Haryana: PPIC India Program; 2000.
7. Setiyono TD, Walters DT, Cassman KG, Witt C, Dobermann A. Estimating the nutrient uptake requirements of maize. Field Crops Res. 2010;118:158-68.
8. Subbiah BV, Asija GL. A rapid procedure for the determination of available nitrogen in soils. Curr Sci. 1956;25:259-60.
9. Timsina J, Jat ML, Majumdar K. Rice-maize systems of South Asia: current status, future prospects and research priorities for nutrient management. Plant Soil. 2010;335:65-82.
10. Tiwari KN. Rice production and nutrient management in India. Better Crop Int. 2002;16:18-22.
11. Walkley A, Black CA. Estimation of soil organic carbon by the Chromic acid titration method. Soil Sci. 1934;37:28-9.