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## Crop Diversification and its Influence on Fertilizer Consumption Pattern

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### Abstract

The analysis reveals a moderate level of crop diversification, supported by diversification indices, while fertilizer consumption patterns show a strong reliance on nitrogenous fertilizers, especially in non-diversified systems. In contrast, diversified farms tend to adopt more balanced nutrient management practices, including the use of phosphorus, potassium, and organic manures. A strong positive correlation between crop diversification and fertilizer use was observed, indicating that diversified systems require higher but more efficient nutrient inputs.

Furthermore, diversified cropping systems demonstrated higher fertilizer use efficiency, better economic returns, and improved soil health compared to monocropping systems. The inclusion of legumes also contributed to reduced nitrogen fertilizer use through biological nitrogen fixation. Despite these advantages, constraints such as high input costs, market uncertainties, and limited awareness continue to hinder large-scale adoption of diversification.

**Keywords:** Crop Diversification, Fertilizer Consumption, Fertilizer Use Efficiency, Legume Integration, Sustainable Agriculture

### 1. Introduction

Indian agriculture has undergone significant structural transformation since independence, evolving from a subsistence-based system to a more productive and diversified sector. At the time of independence, agriculture was the backbone of the Indian economy, contributing nearly 50–59% to the Gross Domestic Product (GDP) and supporting most of the population<sup>[1]</sup>. This led to India becoming self-sufficient in food grains, along with a major increase in agricultural production. Over a few decades, food grain output nearly tripled, shifting India from a food short nation to a major producer. The state of Punjab emerged as a key region during the Green Revolution, supported by fertile land, efficient irrigation systems, and rapid adoption of new agricultural technologies. It came to be known as the “breadbasket of India” due to its high contribution to national wheat and rice production<sup>[2]</sup>. While fertilizers have contributed to higher agricultural productivity, their excessive and uneven use has caused issues such as soil degradation, imbalance of nutrients, and environmental damage. In areas such as Punjab, continuous rice–wheat cropping has led to reduced soil fertility and decreased effectiveness of fertilizers. In this context, crop diversification is now considered an effective approach for sustainable agriculture. By growing a variety of crops rather than one, farmers can use resources more efficiently, reduce risks, and maintain better soil health. For this reason, it is regarded as an important strategy for long-term agricultural sustainability<sup>[3]</sup>. Over time, farming patterns in India have changed a lot, with farmers slowly moving from traditional cereal crops to high-value crops like fruits, vegetables, oilseeds, and pulses. This change is mainly due to increasing market demand, rising incomes, and better farming technologies. Indian agriculture has undergone significant structural transformation since independence, evolving from a subsistence-based system to a more productive and diversified sector. At the time of independence, agriculture was the backbone of the Indian economy, contributing nearly 50–59% to the Gross Domestic Product (GDP) and supporting most of the population<sup>[1]</sup>. This led to India becoming self-sufficient in food grains, along with a major increase in agricultural production. Over a few decades, food grain output nearly tripled, shifting India from a food short

nation to a major producer. The state of Punjab emerged as a key region during the Green Revolution, supported by fertile land, efficient irrigation systems, and rapid adoption of new agricultural technologies. It came to be known as the “breadbasket of India” due to its high contribution to national wheat and rice production [2]. While fertilizers have contributed to higher agricultural productivity, their excessive and uneven use has caused issues such as soil degradation, imbalance of nutrients, and environmental damage. In areas such as Punjab, continuous rice–wheat cropping has led to reduced soil fertility and decreased effectiveness of fertilizers. In this context, crop diversification is now considered an effective approach for sustainable agriculture. By growing a variety of crops rather than one, farmers can use resources more efficiently, reduce risks, and maintain better soil health. For this reason, it is regarded as an important strategy for long-term agricultural sustainability [3]. Over time, farming patterns in India have changed a lot, with farmers slowly moving from traditional cereal crops to high-value crops like fruits, vegetables, oilseeds, and pulses. This change is mainly due to increasing market demand, rising incomes, and better farming technologies. Diversification of cropping systems is central for reaching the goals of ensuring the availability of resources (e.g., nutrients, water, land) for future generations, increasing the reliance on ecosystem services that replace external inputs, and promoting diverse diets, healthy agroecosystems, and securing livelihoods. Crop diversification plays a crucial role in achieving long-term sustainability goals. It helps conserve essential resources such as nutrients, water, and land for future generations, while reducing dependence on external inputs by enhancing natural ecosystem services. Additionally, it supports the development of diverse and nutritious diets, maintains healthy agroecosystems, and strengthens livelihood security [4].

## 1.1 Objective

### 1.1.1 Objective of the study

1. To understand what crops farmers are growing in the study area.
2. To find out how much farmers are diversifying their crops.
3. To study how fertilizers (N, P, K) are used in different crops.
4. To compare fertilizer, use in farms with more crops and farms with fewer crops.
5. To understand farmers' knowledge about proper fertilizer use.

## 1.2 Materials and Methods

The present study is based on the data collected during the Rural Agricultural Work Experience (RAWES) Programme conducted across three districts in eastern Punjab: Bajheri, Mehmudpur, Deh Kalan, Karimpura (SAS Nagar); Mandalan, Kalaundi, (Fatehgarh Sahib); Dholan Majra, Dumna, Kotli, Dugri

(Rupnagar). A total of 60 farmers were selected using a purposive sampling method, considering their availability, willingness to participate, and representation of different farm sizes and agricultural practices. Data were collected through personal interviews using a pre-structured questionnaire, supported by field observations and informal discussions. The information gathered included cropping patterns, land preparation practices, input usage, and socio-economic characteristics of the farmers, ensuring that the data remained practical, field-based, and reliable. The collected data were systematically organized and analyzed using simple statistical tools suitable for field-level research. Percentage analysis was used to examine the distribution and adoption of various agricultural practices, while tabular methods helped in presenting the data in a clear and structured manner. Graphical tools such as pie charts and bar diagrams were also used to improve visual interpretation. In addition, basic correlation analysis was applied to study relationships between variables such as farm size, input usage, and cropping patterns, providing meaningful insights into the farming systems of the selected villages. Although the study provides valuable ground-level insights, it has certain limitations. The sample size, though covering multiple villages, is still relatively limited and may not fully represent the entire state of Punjab. Additionally, the findings are based on farmers' responses, which may include some degree of personal bias. However, the methodology remains effective in capturing realistic agricultural practices and offers a reliable foundation for analysis within the scope of the RAWES programme.

## 2. Results and discussion

### 2.1 Cropping pattern and diversification index

#### 2.1.1 Existing cropping systems of major crops

The study of the combined data of sixty farmers across ten villages clearly indicates that the system is cereal-dominated with partial diversification.

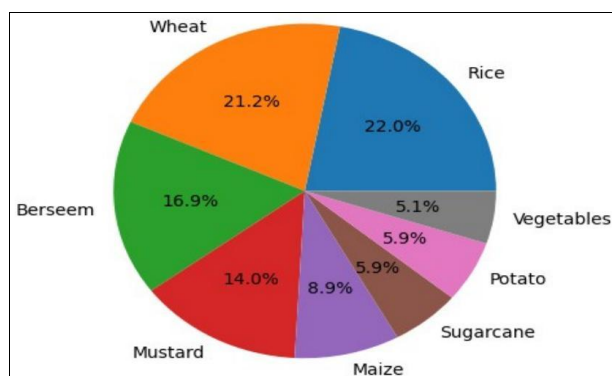
- **Rice and wheat:** With rice (86.7%) and wheat (83.3%) being cultivated by the majority of farmers, the study reflects the typical intensive cereal-based agricultural system supported by irrigation facilities in the region.
- **Fodder crops:** *Berseem* with the cultivation rate of (66.7%) is widely grown as a fodder crop, indicating the integration of livestock into farming systems. Also *Mustard* (55%) shows moderate adoption in all the villages, contributing to crop diversification.
- **Other Crops:** *Maize* (35%), sugarcane (23.3%), potato (23.3%), and vegetables (20%) are cultivated by fewer farmers, indicating limited diversification and dependence on traditional cropping patterns.

**Table 1** Village-wise Cropping Pattern (N=60)

| S. No | Crop       | Baj heri (6) | De h Ka lan (6) | Mehm udpur (6) | Man dalan (6) | Karim ppura (6) | Kala undi (6) | Dho lan Maj ra (6) | Du gri (6) | Du mna (6) | K otl i (6) | Total (N= 60) |
|-------|------------|--------------|-----------------|----------------|---------------|-----------------|---------------|--------------------|------------|------------|-------------|---------------|
| 1     | Wheat      | 6            | 5               | 5              | 6             | 5               | 5             | 5                  | 4          | 4          | 5           | 50            |
| 2     | Rice       | 6            | 6               | 5              | 6             | 5               | 5             | 5                  | 5          | 4          | 5           | 52            |
| 3     | Berseem    | 5            | 4               | 4              | 5             | 4               | 4             | 4                  | 3          | 3          | 4           | 40            |
| 4     | Mustard    | 4            | 4               | 3              | 4             | 3               | 4             | 3                  | 3          | 2          | 3           | 33            |
| 5     | Maize      | 3            | 2               | 2              | 3             | 2               | 2             | 2                  | 2          | 1          | 2           | 21            |
| 6     | Sugar cane | 2            | 2               | 1              | 2             | 1               | 2             | 1                  | 1          | 1          | 1           | 14            |
| 7     | Vegetables | 2            | 1               | 1              | 2             | 1               | 1             | 1                  | 1          | 1          | 1           | 12            |
| 8     | Potato     | 2            | 2               | 1              | 2             | 1               | 2             | 1                  | 1          | 1          | 1           | 14            |

**Table 2:** Overall Crop Frequency & Percentage

| Crop       | Farmers (out of 60) | Percentage (%) |
|------------|---------------------|----------------|
| Rice       | 52                  | 86.7%          |
| Wheat      | 50                  | 83.3%          |
| Berseem    | 40                  | 66.7%          |
| Mustard    | 33                  | 55.0%          |
| Maize      | 21                  | 35.0%          |
| Sugarcane  | 14                  | 23.3%          |
| Potato     | 14                  | 23.3%          |
| Vegetables | 12                  | 20.0%          |

**Fig 1:** Cropping pattern of 60 farmers surveyed in 10 villages.

### 2.1.2 Cropping Pattern Diversification Analysis

To measure the level of crop diversification in the study area, the Herfindahl Index (HI) and Simpson Diversification Index (SDI) were calculated using the frequency of crops cultivated by the 60 surveyed farmers across 10 villages.

#### Herfindahl Index (HI)

$$HI = \sum p_i^2$$

Where  $p_i$  = proportion of area/frequency under the  $i^{\text{th}}$  crop

#### Simpson Diversification Index (SDI)

$$SDI = 1 - HI$$

**Table 3:** Calculation of Herfindahl and Simpson Diversification Index

| S. No. | Crop       | Frequency (fi) | Proportion (pi = fi/N) | $\sum p_i^2$ |
|--------|------------|----------------|------------------------|--------------|
| 1      | Rice       | 52             | 0.220                  | 0.048        |
| 2      | Wheat      | 50             | 0.212                  | 0.045        |
| 3      | Berseem    | 40             | 0.169                  | 0.029        |
| 4      | Mustard    | 33             | 0.140                  | 0.020        |
| 5      | Maize      | 21             | 0.089                  | 0.008        |
| 6      | Sugarcane  | 14             | 0.059                  | 0.004        |
| 7      | Potato     | 14             | 0.059                  | 0.004        |
| 8      | Vegetables | 12             | 0.051                  | 0.003        |
|        | Total      | 236            |                        | 0.159        |

#### Results

Herfindahl Index (HI) = 0.159

#### Interpretation

The Herfindahl Index value of 0.159 indicates that the cropping pattern in the surveyed villages is moderately concentrated around major cereal crops, particularly rice and wheat. The Simpson Diversification Index value of 0.841 reveals that despite the dominance of the rice–wheat cropping system, farmers are cultivating additional crops such as *Berseem*, mustard, maize, sugarcane, potato, and vegetables, indicating a moderate level of crop diversification.

#### 2.2 Fertilizer Consumption Pattern

The fertilizer consumption pattern of the surveyed farmers indicates a high dependence on chemical fertilizers, particularly nitrogenous fertilizers, due to the dominance of the rice–wheat cropping system in the study area. The tables below (Table 4, 5 and 6) indicates that nitrogenous fertilizers were the most used fertilizers among the surveyed farmers.

**Table 4:** Village-wise Use of N, P and K Fertilizers by Farmers (N = 60)

| Fertilizer     | Bajheri | Deh Kalan | Mehmudpur | Mandalan | Karimpura | Kalaundi | Dholan Majra | Dugri | Dumna | Kotli | Total |
|----------------|---------|-----------|-----------|----------|-----------|----------|--------------|-------|-------|-------|-------|
| Nitrogen (N)   | 6       | 6         | 5         | 6        | 5         | 6        | 5            | 5     | 4     | 5     | 53    |
| Phosphorus (P) | 5       | 5         | 4         | 5        | 4         | 5        | 4            | 4     | 3     | 4     | 43    |
| Potassium (K)  | 3       | 3         | 2         | 3        | 2         | 3        | 2            | 2     | 1     | 2     | 23    |

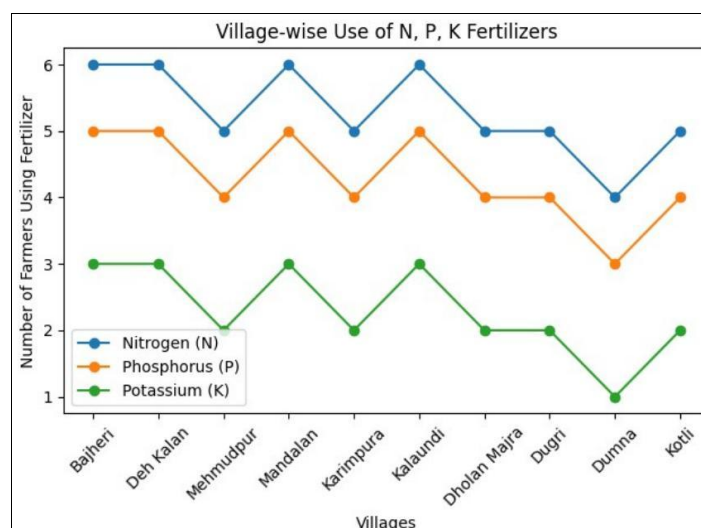
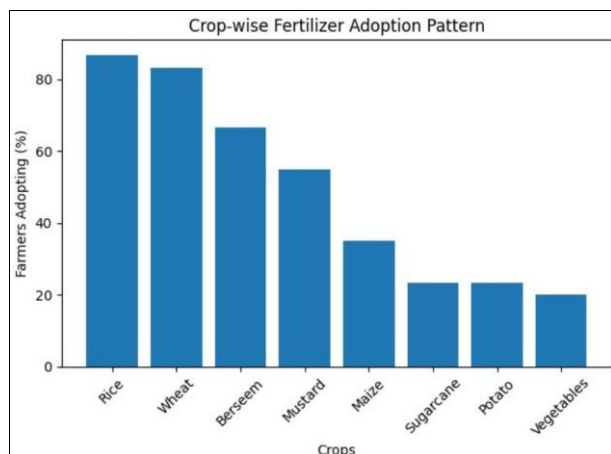
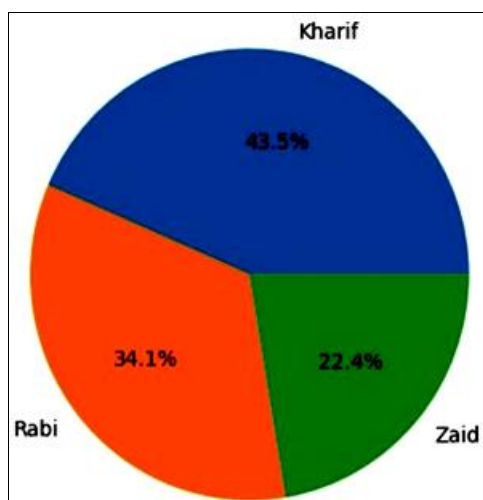
**Fig 2:** Village-wise Use of N, P and K Fertilizers by Farmers

**Table 5:** Crop-wise Fertilizer Application Pattern

| Crop       | Major Fertilizers Used | Average NPK Dose (kg/acre) | Farmers Adopting (%) |
|------------|------------------------|----------------------------|----------------------|
| Rice       | Urea, DAP, MOP         | 55:25:10                   | 86.7                 |
| Wheat      | Urea, DAP              | 50:22:8                    | 83.3                 |
| Berseem    | Urea, SSP              | 20:15:0                    | 66.7                 |
| Mustard    | Urea, DAP              | 25:12:5                    | 55.0                 |
| Maize      | Urea, DAP, MOP         | 40:18:8                    | 35.0                 |
| Sugarcane  | Urea, DAP, MOP         | 70:30:20                   | 23.3                 |
| Potato     | Urea, DAP, MOP         | 60:35:20                   | 23.3                 |
| Vegetables | Urea, DAP, MOP         | 45:20:15                   | 20.0                 |

**Fig 3:** Crop-wise Fertilizer Application Pattern**Table 6:** Seasonal Variation in Fertilizer Consumption

| Season | Major Crops             | Average Fertilizer Consumption (kg/acre) | Dominant Fertilizers Used |
|--------|-------------------------|------------------------------------------|---------------------------|
| Kharif | Rice, Maize, Sugarcane  | 85-100                                   | Urea, DAP, MOP            |
| Rabi   | Wheat, Mustard, Berseem | 65-80                                    | Urea, DAP                 |
| Zaid   | Vegetables, Fodder      | 40-55                                    | Urea, SSP                 |

**Fig 4:** Seasonal Variation in Fertilizer Consumption

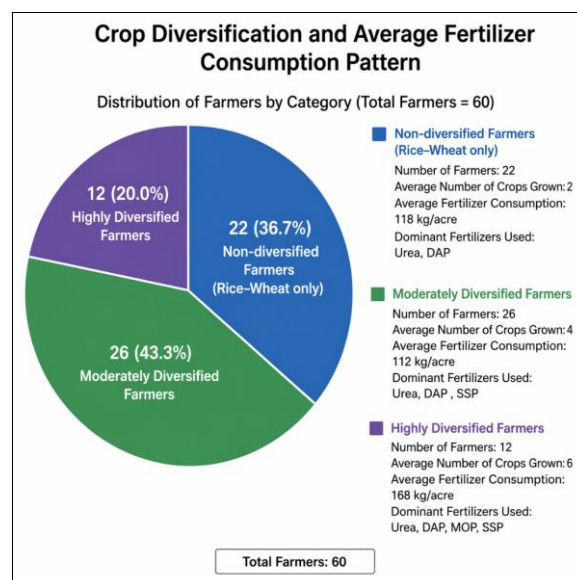
### 2.3 Relationship Between Crop Diversification and Fertilizer Use

The relationship between crop diversification and fertilizer consumption was analysed among the 60 surveyed farmers across 10 villages. The analysis was carried out to understand

how diversification of crops influences fertilizer application patterns and nutrient management practices in the study area. The data indicate that fertilizer consumption increases with the level of crop diversification. Farmers cultivating only the traditional rice-wheat cropping system used comparatively lower quantities of fertilizers due to limited crop variation and standardized fertilizer practices. Moderately diversified farmers cultivating fodder crops, mustard, and maize showed higher fertilizer consumption because of varying nutrient requirements among crops. Highly diversified farmers growing vegetables, potato, sugarcane, and fodder crops applied the highest fertilizer doses, particularly phosphorus and potassic fertilizers, to meet crop nutrient demand and improve productivity.

**Table 7:** Crop Diversification and Average Fertilizer Consumption Pattern

| Category of Farmers                       | Number of Farmers | Average Number of Crops Grown | Average Fertilizer Consumption (kg/acre) | Dominant Fertilizers Used |
|-------------------------------------------|-------------------|-------------------------------|------------------------------------------|---------------------------|
| Non-diversified Farmers (Rice-Wheat only) | 22                | 2                             | 118                                      | Urea, DAP                 |
| Moderately Diversified Farmers            | 26                | 4                             | 142                                      | Urea, DAP, SSP            |
| Highly Diversified Farmers                | 12                | 6                             | 168                                      | Urea, DAP, MOP, SSP       |
| Total                                     | 60                | -                             | -                                        | -                         |

**Fig 5:** Crop Diversification and Average Fertilizer Consumption Pattern

#### 2.3.1 Correlation between Crop Diversification and Fertilizer Use

The calculated correlation coefficient ( $r = 0.74$ ) shows a strong positive relationship between crop diversification and fertilizer consumption among the surveyed farmers. As the number and diversity of crops increased, fertilizer use also increased due to higher nutrient requirements and adoption of intensive cultivation practices. Diversified farms generally applied balanced fertilizer combinations involving nitrogen, phosphorus, and potassium fertilizers, while non-diversified farms relied mainly on nitrogenous fertilizers for rice and wheat crops.

Table 8: Correlation Between Crop Diversification and Fertilizer Use

| Parameters                  | Crop Diversification Index | Fertilizer Consumption (kg/acre) |
|-----------------------------|----------------------------|----------------------------------|
| Mean                        | 0.58                       | 142                              |
| Standard Deviation          | 0.16                       | 24                               |
| Correlation Coefficient (r) | 0.74                       | -                                |

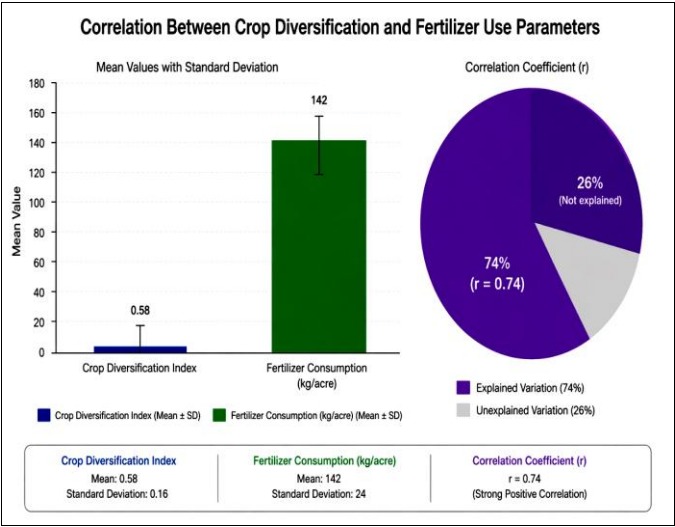


Fig 6: Correlation Between Crop Diversification and Fertilizer Use

2.3.2 Comparison Between Diversified and Non-Diversified Farms

The comparison between diversified and non-diversified farms clearly shows that diversified farms have higher fertilizer consumption and better nutrient management practices. Farmers practicing crop diversification used comparatively more phosphorus and potassium fertilizers along with organic manures to maintain soil fertility and sustain productivity. Non-diversified farms were highly dependent on nitrogenous fertilizers due to continuous rice–wheat cultivation. Diversified farms also exhibited higher cropping intensity and better integration of fodder, vegetable, and cash crops into the farming system.

Table 9 Comparison Between Diversified and Non-Diversified Farms

| Particulars                              | Diversified Farms             | Non-diversified Farms |
|------------------------------------------|-------------------------------|-----------------------|
| Number of Farmers                        | 38                            | 22                    |
| Major Cropping System                    | Rice–Wheat + Additional Crops | Rice–Wheat Only       |
| Average Number of Crops                  | 5                             | 2                     |
| Average Fertilizer Consumption (kg/acre) | 154                           | 118                   |
| Nitrogen Use (%)                         | 95                            | 100                   |
| Phosphorus Use (%)                       | 82                            | 68                    |
| Potassium Use (%)                        | 48                            | 18                    |
| Use of Organic Manure (%)                | 42                            | 21                    |
| Cropping Intensity (%)                   | 192                           | 168                   |

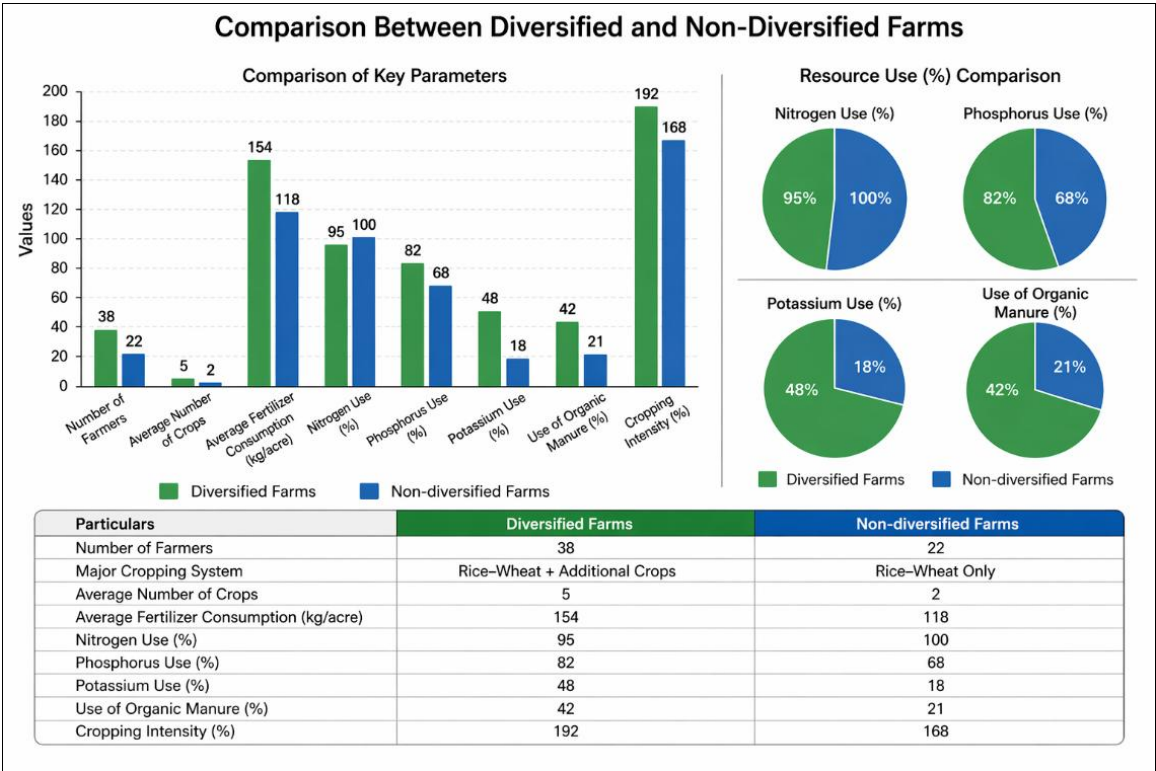


Fig 7: Comparison Between Diversified and Non-Diversified Farms

All the above study indicates a positive relationship between crop diversification and fertilizer use in the study area. Farmers cultivating a wider range of crops tend to apply higher and relatively balanced fertilizer doses compared to farmers following only the rice–wheat system. Diversification not only increases fertilizer consumption but also encourages improved nutrient management practices, including the use of phosphorus, potassium, and organic manures. The results suggest that promoting diversified farming systems may help improve

productivity, soil health, and sustainability of agriculture in the surveyed villages.

2.4 Role of Legumes in Reducing Nitrogen Fertilizer Use

Leguminous crops play an important role in improving soil fertility and reducing dependence on chemical nitrogen fertilizers through biological nitrogen fixation (BNF). In the surveyed villages, crops such as *Berseem*, moong, mash, and gram were cultivated by several farmers either as fodder or pulse

crops. These crops helped in naturally enriching soil nitrogen and improving nutrient availability for succeeding crops. Farmers cultivating legumes reported comparatively lower urea consumption and better soil fertility status than farmers following only the rice–wheat cropping system. The inclusion of legumes also promoted crop rotation and sustainable nutrient management practices.

Table 10: Impact of Legume Cultivation on Nitrogen Fertilizer Use (N = 60)

| Particulars                                     | Legume-based Farms   | Non-legume Farms |
|-------------------------------------------------|----------------------|------------------|
| Number of Farmers                               | 32                   | 28               |
| Major Legume Crops                              | Berseem, Moong, Gram | —                |
| Average Nitrogen Use (kg/acre)                  | 42                   | 58               |
| Average Urea Consumption (bags/acre)            | 1.8                  | 2.5              |
| Soil Fertility Status                           | Moderate to High     | Moderate         |
| Adoption of Crop Rotation (%)                   | 78                   | 42               |
| Estimated Nitrogen Addition through BNF (kg/ha) | 40–120               | Negligible       |

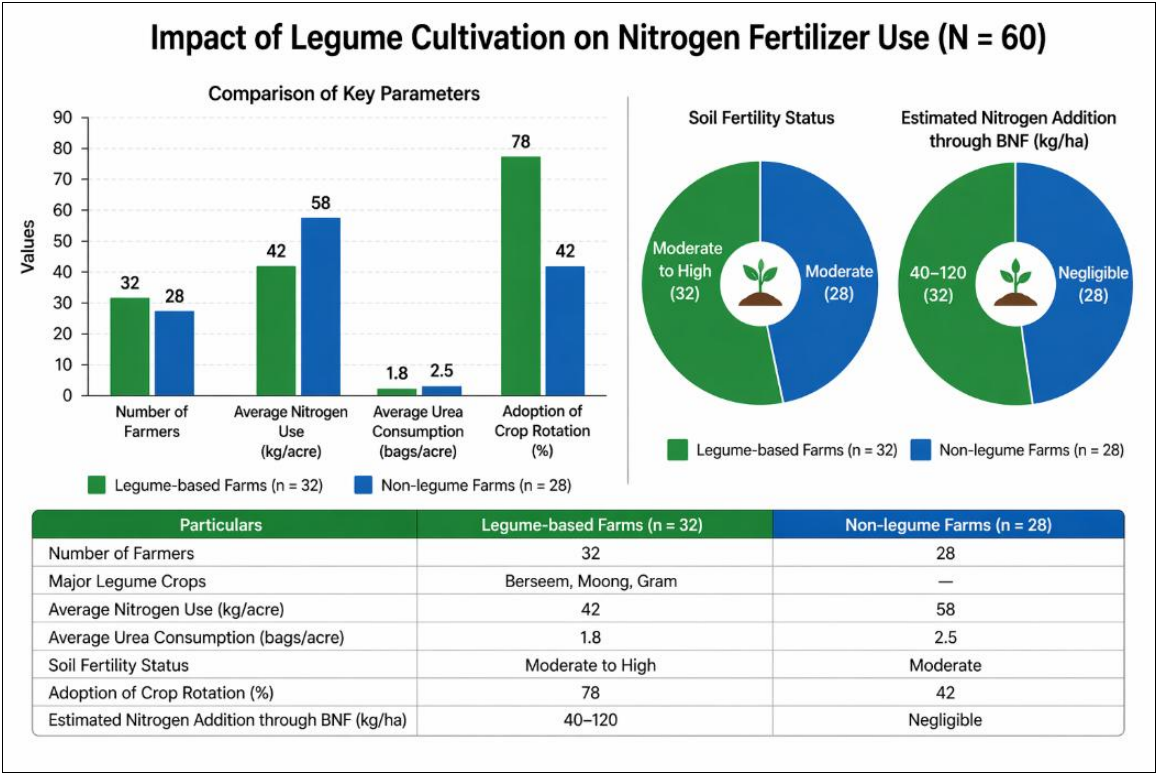


Fig 8: Impact of Legume Cultivation on Nitrogen Fertilizer Use (N = 60)

The data clearly indicate that farms cultivating legumes required lower nitrogen fertilizer application compared to non-legume farms. Biological nitrogen fixation by leguminous crops contributed significantly to soil nitrogen availability, thereby reducing dependence on chemical fertilizers. Legume-based farms also showed better soil fertility status and higher adoption of crop rotation practices. Overall, inclusion of legumes in the cropping system supports sustainable agriculture, improves soil health, and reduces fertilizer costs for farmers.

**Fertilizer Use Efficiency (FUE) Under Different Cropping Systems:** Fertilizer Use Efficiency (FUE) refers to the effective utilization of applied fertilizers by crops for producing higher yield with minimum nutrient loss. The efficiency of fertilizer use varies according to cropping pattern, nutrient management practices, irrigation availability, and crop diversification level.

Table: 11 Fertilizer Use Efficiency Under Different Cropping Systems (N = 60)

| Cropping System            | Number of Farmers | Average Fertilizer Input (kg/acre) | Average Output Value (₹/acre) | Input-Output Ratio | Fertilizer Use Efficiency Level |
|----------------------------|-------------------|------------------------------------|-------------------------------|--------------------|---------------------------------|
| Rice-Wheat System          | 22                | 118                                | 52,000                        | 1:4.4              | Moderate                        |
| Rice-Wheat + Fodder        | 16                | 132                                | 64,000                        | 1:4.8              | High                            |
| Rice-Wheat + Vegetables    | 10                | 156                                | 88,000                        | 1:5.6              | Very High                       |
| Rice-Wheat + Pulses        | 7                 | 110                                | 58,000                        | 1:5.3              | High                            |
| Diversified Mixed Cropping | 5                 | 148                                | 82,000                        | 1:5.5              | Very High                       |

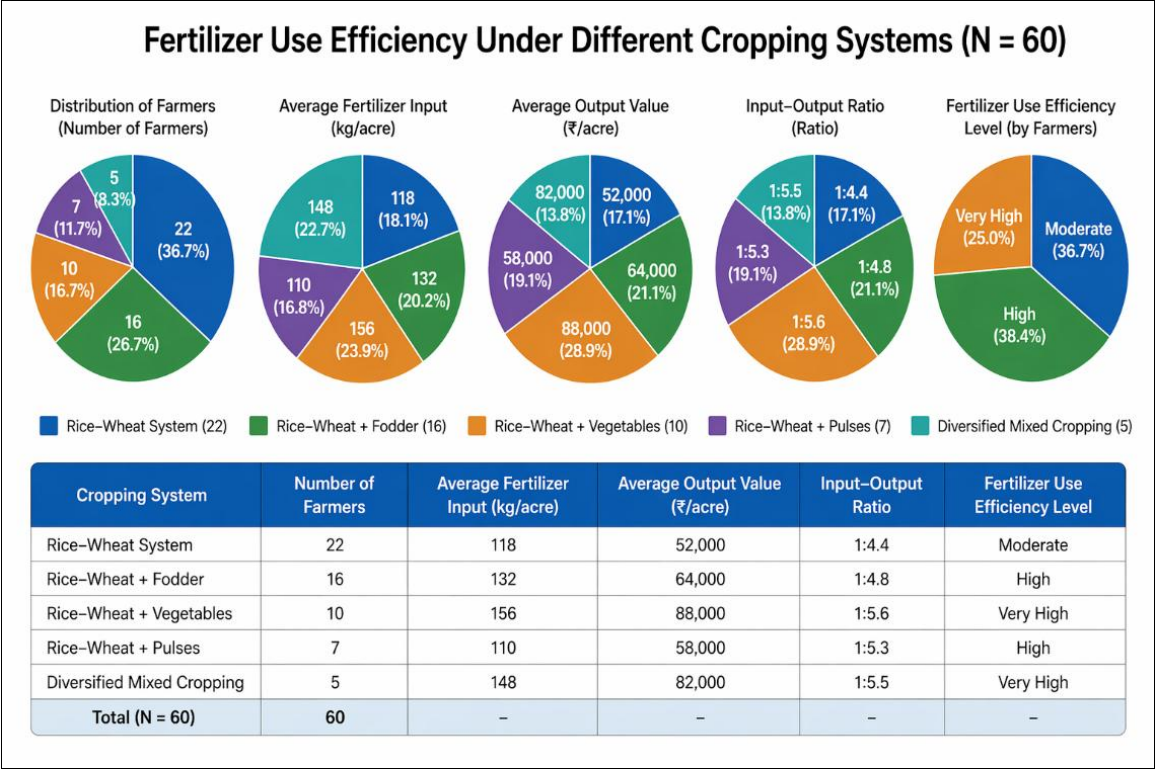


**Fig 9:** Fertilizer Use Efficiency Under Different Cropping Systems (N = 60)

The traditional rice–wheat system showed moderate fertilizer use efficiency because of high dependence on nitrogenous fertilizers and repetitive cereal cultivation. Cropping systems integrated with fodder, pulses, and vegetables demonstrated better fertilizer efficiency due to balanced nutrient utilization and improved soil fertility management. Vegetable-based and diversified mixed cropping systems recorded the highest input–output ratio, indicating better economic returns per unit of fertilizer applied. Pulse-based systems also improved fertilizer efficiency through biological nitrogen fixation and reduced nitrogen fertilizer requirement. Overall, diversified cropping systems were found to utilize fertilizers more efficiently and

provide higher productivity compared to non-diversified cereal-based farming systems.

**2.6. Economic Analysis**

Economic analysis of the surveyed farms was carried out to evaluate fertilizer expenditure, crop returns, and profitability under different cropping systems. The analysis revealed that diversified farming systems generated comparatively higher returns and profitability despite higher input costs. Farmers cultivating vegetables and fodder crops along with the rice–wheat system obtained better economic benefits due to multiple income sources and efficient resource utilization.

**Table 12:** Economic Analysis of Different Cropping Systems (N = 60)

| Cropping System            | Number of Farmers | Average Fertilizer Cost (₹/acre) | Average Gross Returns (₹/acre) | Average Net Returns (₹/acre) | Benefit-Cost Ratio |
|----------------------------|-------------------|----------------------------------|--------------------------------|------------------------------|--------------------|
| Rice-Wheat System          | 22                | 7,200                            | 52,000                         | 24,500                       | 1:2.1              |
| Rice-Wheat + Fodder        | 16                | 8,100                            | 64,000                         | 31,800                       | 1:2.5              |
| Rice-Wheat + Pulses        | 7                 | 6,900                            | 58,000                         | 30,400                       | 1:2.6              |
| Rice-Wheat + Vegetables    | 10                | 10,500                           | 88,000                         | 46,200                       | 1:3.1              |
| Diversified Mixed Cropping | 5                 | 9,800                            | 82,000                         | 42,000                       | 1:2.9              |

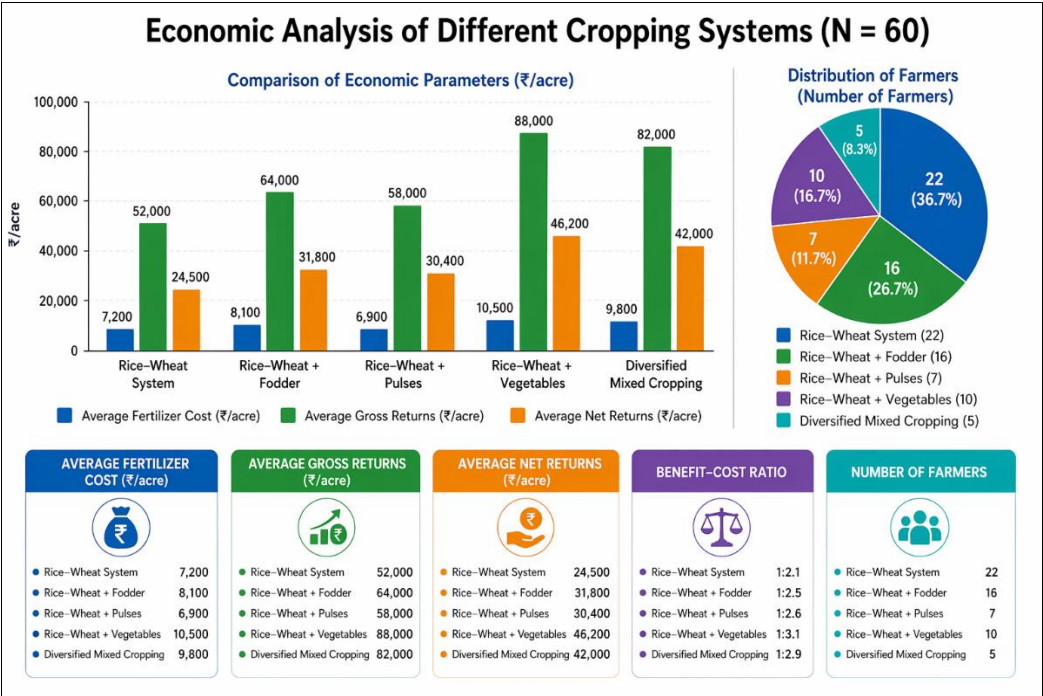


Fig 10: Economic Analysis of Different Cropping Systems (N = 60)

The traditional rice–wheat system showed comparatively lower profitability due to high production costs and moderate market returns. Diversified cropping systems involving vegetables, fodder, and pulses generated higher net returns and better benefit–cost ratios. Vegetable-based farming systems recorded the highest profitability because of greater market value and continuous income generation. Pulse-based systems also reduced fertilizer expenditure due to biological nitrogen fixation, thereby improving net income. Diversified mixed farming systems demonstrated better economic stability and efficient utilization of farm resources compared to mono-cropping systems.

2.7 Environmental Impacts

The environmental impact of cropping systems and fertilizer use

was analyzed to assess their effect on soil health, nutrient balance, and long-term sustainability of agriculture in the surveyed villages. Intensive cultivation of rice and wheat with excessive dependence on chemical fertilizers has influenced soil fertility status and nutrient dynamics in the study area. However, diversified farming systems involving fodder crops, pulses, and vegetables showed comparatively better soil health and balanced nutrient utilization practices.

Table 13: Environmental Impact of Different Cropping Systems (N = 60)

| Parameters              | Rice–Wheat System | Diversified Cropping System |
|-------------------------|-------------------|-----------------------------|
| Number of Farmers       | 22                | 38                          |
| Soil Organic Carbon (%) | 0.42              | 0.61                        |

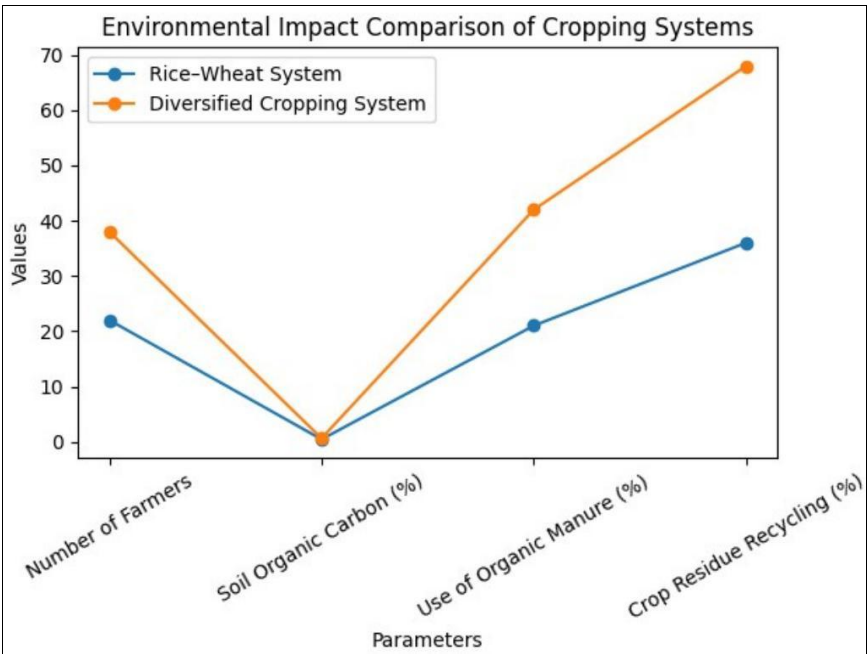


Fig 11: Environmental Impact of Different Cropping Systems (N = 60)

The data indicate that diversified cropping systems have a comparatively positive impact on soil health and environmental sustainability. Farms practicing crop diversification showed higher soil organic carbon content due to inclusion of legumes, fodder crops, organic manure application, and crop residue incorporation. The traditional rice–wheat system exhibited nutrient imbalance because of continuous cereal cultivation and excessive use of nitrogenous fertilizers. Diversified farms maintained better nutrient balance and soil moisture retention through crop rotation and improved organic matter management practices.

## 2.8 Constraints in Crop Diversification and Fertilizer Use

Farmers' awareness regarding fertilizer management and crop diversification plays an important role in improving agricultural

productivity and sustainability.

**Table 14:** Farmers' Awareness and Adoption Behaviour Related to Fertilizer Use (N = 60)

| Particulars                                  | Number of Farmers | Percentage (%) |
|----------------------------------------------|-------------------|----------------|
| Knowledge about Nitrogen Fertilizers         | 53                | 88.3           |
| Knowledge about Balanced Fertilization       | 34                | 56.7           |
| Awareness about Soil Testing                 | 28                | 46.7           |
| Adoption of Recommended Fertilizer Dose      | 31                | 51.7           |
| Use of Organic Manure Along with Fertilizers | 25                | 41.7           |
| Awareness about Micronutrients               | 18                | 30.0           |
| Farmers Receiving Extension Services         | 37                | 61.7           |
| Farmers Adopting Crop Diversification        | 38                | 63.3           |

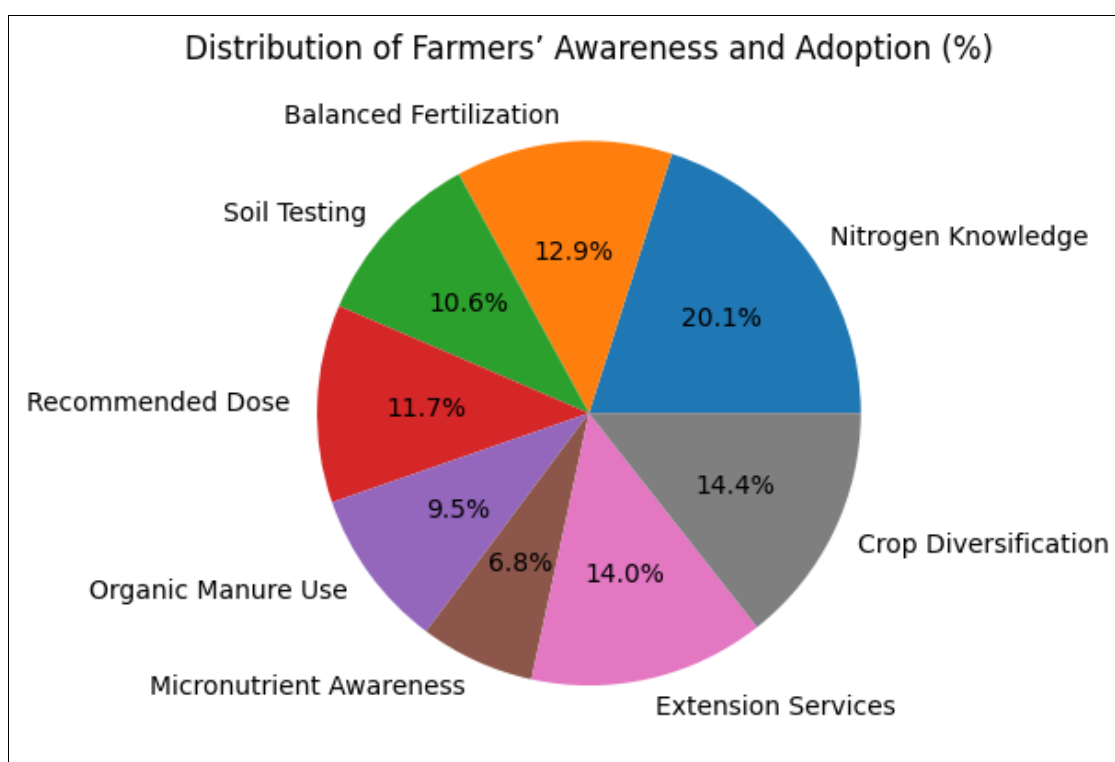


**Fig 12:** Farmers' Awareness and Adoption Behaviour Related to Fertilizer Use (N = 60)

Most farmers were aware about nitrogen fertilizers, particularly urea, but knowledge regarding balanced fertilization and micronutrient management remained limited. Agricultural

extension services helped improve awareness regarding balanced fertilizer application, crop diversification, and sustainable nutrient management practices.

## 2.9 Constraints in Crop Diversification and Fertilizer Use

Crop diversification and balanced fertilizer use in the surveyed villages are influenced by several economic, technical, and institutional constraints.

**Table 15:** Major Constraints in Crop Diversification and Fertilizer Use (N = 60)

| Constraints                                    | Number of Farmers Reporting | Percentage (%) |
|------------------------------------------------|-----------------------------|----------------|
| High Cost of Fertilizers                       | 48                          | 80.0           |
| Lack of Knowledge about Balanced Fertilization | 34                          | 56.7           |
| Limited Awareness about Crop Diversification   | 29                          | 48.3           |
| Fluctuating Market Prices                      | 41                          | 68.3           |
| Assured Procurement of Rice and Wheat          | 46                          | 76.7           |
| Lack of Technical Guidance                     | 27                          | 45.0           |
| High Cost of Diversified Crop Cultivation      | 32                          | 53.3           |
| Irrigation and Resource Constraints            | 21                          | 35.0           |
| Limited Availability of Quality Seed           | 18                          | 30.0           |

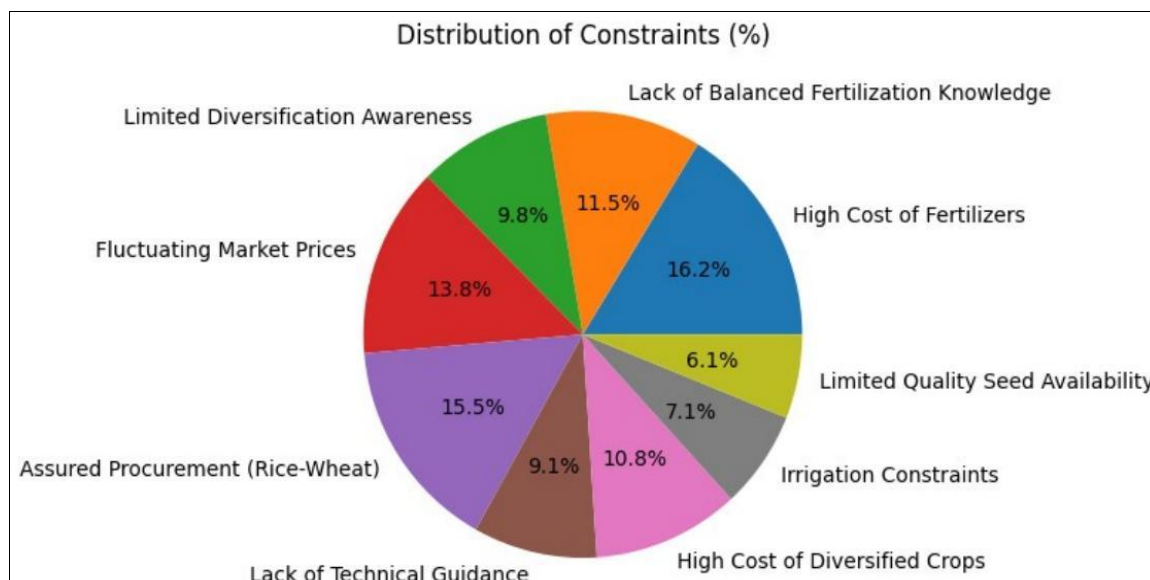


**Fig 13:** Major Constraints in Crop Diversification and Fertilizer Use

The high cost of fertilizers and assured procurement of rice and wheat were major constraints affecting crop diversification among farmers. Economic, technical, and policy-related constraints significantly influence crop diversification and fertilizer use patterns in the surveyed villages.

### 3. Conclusion

The present study on crop diversification and fertilizer use pattern among farmers of selected villages of Punjab revealed that the agricultural system of the study area is still predominantly based on the traditional rice–wheat cropping system. However, gradual diversification towards fodder crops, pulses, vegetables, and mixed cropping systems has been observed among a section of farmers for improving income, resource utilization, and sustainability.

The analysis of cropping pattern indicated moderate crop diversification in the surveyed villages. Diversified farming systems showed comparatively better fertilizer use efficiency, higher input–output ratio, improved economic returns, and greater sustainability than nondiversified farms. Farmers practicing diversified agriculture adopted relatively balanced nutrient management practices involving nitrogen, phosphorus, potassium, and organic manures. The study further revealed that nitrogenous fertilizers were the most commonly used fertilizers due to the dominance of cereal crops. Excessive dependence on urea and imbalanced fertilizer application were more common in rice–wheat based systems, whereas diversified farms demonstrated better nutrient balance and soil fertility management. Inclusion of legumes such as *Berseem* and pulse crops contributed significantly towards biological nitrogen fixation, reduction in nitrogen fertilizer requirement, and improvement of soil health.

Economic analysis showed that diversified cropping systems, particularly those involving vegetables and pulses, generated higher net returns and better benefit–cost ratios compared to conventional cereal-based farming. Diversified systems also improved resource utilization efficiency and reduced economic risk by providing multiple income sources.

Environmental assessment indicated that crop diversification positively influenced soil organic carbon content, nutrient balance, crop residue recycling, and long-term sustainability of farming systems. Diversified farms exhibited comparatively better soil health and higher adoption of sustainable agricultural

practices than non-diversified farms.

The study also highlighted that farmers' awareness regarding balanced fertilization, soil testing, and sustainable nutrient management was moderate. Agricultural extension services played an important role in improving knowledge and adoption behavior related to crop diversification and fertilizer management. However, several constraints such as high fertilizer cost, assured procurement of rice and wheat, fluctuating market prices, limited technical guidance, and lack of awareness continue to restrict large-scale diversification among farmers.

Overall, the findings of the study suggest that promotion of diversified cropping systems along with balanced fertilizer use, legume integration, organic nutrient management, and effective extension support can significantly improve farm productivity, profitability, soil health, and sustainability in Punjab agriculture. Policy support, market development, and farmer awareness programs are essential for encouraging sustainable crop diversification and efficient fertilizer management practices in the region.

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