

Evaluating nutritional yield patterns through diverse cropping systems to enhance nutritional security in the eastern IGP of India

Research Note 48

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ABOUT THIS BRIEF

In rural communities of eastern Indo Gangetic Plains (EIGP), having a restricted range of food choices presents major obstacles to maintaining nutritional health and overall well-being. Numerous families mainly depend on basic crops like wheat and rice, resulting in a repetitive diet that is deficient in vital vitamins, minerals, and proteins. As a result, communities, especially women and children, often experience malnutrition and deficiencies in like iron and vitamins. Preschool children's severe acute malnutrition has increased from 6.6% to 7.7%, which is putting them at high risk of the children (National Family Health Survey-3). To address these complex changes, the on-farm research was set up by the Transforming Agrifood Systems in South Asia (TAFSSA) Initiative under CIMMYT with the partnership of CGIAR Institutes, JEEVIKA, and the Department of Agriculture in Nalanda district of Bihar, India, enhancing the nutritional diversity through cultivating diversified cropping systems.

KEY FINDINGS

1. Following a one-year cropping cycle (consisting of three seasons) on the farm, it was noted that diversified cropping systems surpassed the most common farmer practice in terms of nutritional yield and satisfied higher nutrient requirements per farm annually.
2. In comparison with the existing rice-wheat system, optimizing diversified cropping systems greatly increased yields: protein by 66%, carbohydrates by 87%, fat by over 931%, iron by 878% and zinc yields by 337%, respectively.
3. This improvement could fulfill the extra nutritional requirements of 9–31-person ha⁻¹ yr⁻¹ for protein, 13–68 for carbohydrates, 2–86 for fat, and 4–60 for iron and zinc, in contrast to the traditional rice-wheat system.
4. The main source of nutrition comes from the diversified monsoon and winter crops. Adding short-duration spring crops, enhances agricultural intensification while securing nutrition.

BACKGROUND

In eastern Indo Gangetic Plain (EIGP) of India, the traditional diet in the region is predominantly cereal based, leading to inadequate nutrient intake resulted in 50% of children and women suffer from anemia, while vitamin A deficiency affects over 60% of preschool children and 30% of women (Damerau et al., 2020). The Ministry of Women and Child Development (Government of India) tracks nutritional indicators through the National Family Health Survey (NFHS). The findings from NFHS-5 (2019-21) show that approximately 35% of children under five years of age are stunted, 19% are wasted, and 32% are underweight. According to FAO estimates, around 189 million people in India aged 15 to 49 suffer from undernutrition, with 57% of women being anemic (The State of Food Security and Nutrition in the World, 2020 and 2023). Reports also reveal that about 74% of India's population cannot afford healthy diets, and around 39% of diets are nutritionally inadequate, leading to micronutrient deficiencies. Essential foods like pulses, vegetables, fruits, and protein-rich items are often consumed in insufficient amounts, aggravating malnutrition. To address this, the government has prioritized boosting the production of key pulses and oilseeds, ensuring they are made available through the Public Distribution System (PDS) at affordable prices to improve nutrition. Crop diversification, along with the integration of oilseeds and pulses crops into sustainable intensification, has been recognized as an effective strategy for achieving the objectives of

food and nutritional security, sustainable management of land and water resources (Bijarniya et al., 2024), and enhancing the production of dietary energy, fats, and protein (Dutta et al., 2023). This research trial is designed to evaluate diverse cropping patterns in order to address complex challenges and improve nutritional production for ensuring regional nutritional security.

OBJECTIVES

Increased food security improved dietary diversity, and the advancement of sustainable agricultural practices are the main goals of attaining nutritional outcomes from diversified cropping systems. Through the production of diverse crops, these systems seek to improve the accessibility of nutrients, thereby tackling malnutrition and micronutrient deficiencies in vulnerable populations. Results from the one year of crop rotations on the farm are described in this research brief.



Above: No-tillage chickpea crop at farmer's field in India; photo: Dr. Kajod

DATA AND METHODS

The on-farm trial follows a randomized complete block design, with five scenarios/crop rotations during 2023-24 replicated across the farmers. The five scenarios were constituted in a combination of crop rotations and improved agronomic regenerative agricultural management practices; the details are presented in productivity research note 1. Scenario 1 has adopted a business-as-usual rice-wheat-fallow system under conventional management, scenario 2 was rice-potato-maize system under conventional management, scenario 3 was maize-mustard-mung bean system under zero-till with residue retention as a full conservation agriculture practice, scenario 4 was rice-chickpea-prosomillet system under no tillage with residue retention, scenario 5 was rice-wheat-mung bean system where rice under conventional tillage direct seeding and rest of the crops under no tillage with partial residue retention. These cropping systems were determined through the engagement of various stakeholders, including the community, local private actors, governers, extension personnel, researchers and policy people through

focus group discussions, brainstorming and meetings etc.

Grain quality parameters, including protein, fat, iron (Fe), and zinc (Zn) content, were computed using standardized factors specific to each crop as specified in the Indian food composition table 1 (Longvah et al., 2017). These factors were multiplied by the yield of a particular crop, to calculate the total amount of nutrients obtained from the crop. The yield efficiency of protein, fat, Fe and Zn was calculated based on the annual adult protein, fat, Fe and Zn demand equivalent based on the 58, 30 g and Fe 17 and Zn 12 mg person⁻¹ day⁻¹, respectively, as per the recommendations of the Indian council of medical research (ICMR, 2009).

All the data were tested for normal distribution using the JMP 18 (SAS software) and found satisfactorily in their homogeneity. This research was conducted in RCBD, the ANOVA was constructed as fixed effect scenarios while the replication was used as random effect. The mean of scenario significance differences was separated using the Tukey's Honestly Significance Difference (HSD).

Table 1. Factors are taken for calculation yield of protein, CHO, Fat, Fe and Zn in system under different treatments

Crop	Protein (g 100 ⁻¹ gm)	Carbohydrate (g 100 ⁻¹ gm)	Fat (g 100 ⁻¹ gm)	Fe (ppm)	Zn (ppm)
Wheat	10.59	64.72	1.47	39.70	28.50
Potato	1.54	14.89	0.23	5.70	3.80
Mustard	19.51	16.80	40.19	134.00	40.30
Mung bean	23.90	52.50	1.35	39.30	24.90
Rice	7.94	78.24	0.52	6.50	12.10
Chickpea	18.77	39.56	5.11	67.8	33.7
Maize	8.30	64.77	3.77	24.90	22.70
Prosomillet	10.13	65.55	3.89	12.6	18.2

RESULTS

The nutritional yields of the system were significantly ($p \leq 0.05$) impacted by the various crops and their management techniques (figure 1). The highest system protein yield was recorded under diversified, as shown by rice-potato-maize system (scenario 2) followed by rice-wheat-mung bean (scenario 5) and maize-mustard-mung bean (scenario 3), which proved significantly higher system protein yield over farmers practice (scenario 1). Even though the rice-potato-maize system (scenario 2) provides higher total protein yield due to the bulk production of potatoes, the per unit protein intake could be much lower than the other diversified systems. It might be a potential option to replace the rice-wheat system in peri-urban areas where market risk is less because of a cold storage facility. Additionally, labor availability, especially for harvesting and processing, can significantly impact farmers' productivity and profitability.

The staple foods in this region predominantly include cereal-based rice, which is deeply ingrained in local culinary traditions. The second highest protein yield was reported under rice-wheat-mung bean (Sc 5) and maize-mustard-mung bean (Sc 3). Maize-mustard-mung bean (Sc 3) is the most promising system that can replace rice and provide additional nutrition to the community. The additional yield and high protein content of mung bean during the summer season resulted in a greater overall protein yield. Mung bean is the preferred legume food as a source of protein, and its local production will improve house-level availability. Mung bean serve as a significant source of protein, making them a valuable component of a

balanced diet that not only enhances human health but also contributes to the restoration of soil health. The one-year mean data proved that the rice-potato-maize system (Sc 2) significantly produced the total protein yield by 66.3%, followed by rice-wheat-mung bean (Sc 5) by 29.2% and maize-mustard-mung bean (Sc 3) by 18.3%, respectively. The system basis carbohydrate yield was the highest under the rice-potato-maize system (Sc 2) which was significantly higher compared to other scenarios. The highest potato yield and carbohydrate content enhanced carbohydrate yield in the system. The high carbohydrate yield from a rice-potato-maize cropping system is closely linked to human calories, as carbohydrates are a primary energy source essential for overall food source. Rice is rich in carbohydrates, serving as a dietary foundation for billions of people, while potatoes offer additional vitamins and minerals, such as vitamin C and potassium. The rice-potato-maize cropping system, while beneficial, faces several challenges that can impact its effectiveness and sustainability. Both the crops, potato and maize prices can vary significantly based on supply and demand dynamics while surplus production can drive prices down. Inadequate infrastructure can increase transportation costs, impacting the final prices of both the crops. Remote areas may face higher logistics expenses, which can be passed on to consumers. Also, potato crop require more labor, which may be a challenge in areas facing labor shortages or where migration affects local workforces. Based on the comparative data, the carbohydrate yield in the rice-potato-maize system was found to be 87% greater than that of the farmer practice Sc1 (rice-wheat-fallow).

According to the one-year mean data, the system fat yield of maize-mustard-mung bean (Sc3) increased by 931%, while rice-potato-maize (Sc2) increased by 248% (Figure 1). The maize-mustard-mung bean (Sc3) cropping system has the potential to enhance soil health through the incorporation of diverse crops, such as oilseeds and legumes. In scenario 3, elevated fat content in mustard during the rabi season and an additional yield of mung bean in the summer season.

These factors collectively resulted in a higher overall fat yield for the system compared to Sc1. In India, oilseed crops such as mustard present an opportunity to supplant cereals, owing to their resilience, minimal irrigation requirements, and more favorable market prices. This shift could also reduce reliance on expensive imports, thereby improving the country's self-sufficiency in edible oil production. A significant increase in maize production is essential in India to satisfy the rising demand for ethanol production for petrol blending, as well as to support the expanding poultry, animal feed, starch, and other industries within the country. According to one-year statistics, the rice-potato-maize system (scenario 2) produced the maximum iron (Fe) yield, followed by the maize-mustard-mungbean system (scenario 3). Scenarios 2 and 3 resulted in 878% and 365%, respectively, increase in system Fe yield compared to scenario 1. The highest zinc (Zn) yield was obtained under the rice-potato-maize system (scenario 2) followed by the maize-mustard-mungbean system (scenario 3) as compared to farmer practice (scenario 1). The diversified cropping systems, scenarios 2 and 3 recorded 337% and 79% higher Zn yield than scenario 1 (Figure 2). Adult's nutrient

demands were significantly ($p \leq 0.05$) influenced by different crops and their management practices. The protein demand equivalent basis, diversified system scenarios 2, 5 and 3 could meet the adult protein demand of 77, 60 and 55 -persons $\text{ha}^{-1} \text{yr}^{-1}$ compared to 47 person's $\text{ha}^{-1} \text{yr}^{-1}$ under scenario 1. The diversified system, Sc 2, Sc 5 and Sc 3 could meet the protein demand of 31, 14 and 9 more persons $\text{ha}^{-1} \text{yr}^{-1}$, compared to farmer practice. The carbohydrate adult demand persons $\text{ha}^{-1} \text{yr}^{-1}$ was recorded higher under Sc 2 compared to other diversified system, which was recorded 68 more persons $\text{ha}^{-1} \text{yr}^{-1}$, compared to Sc 1. The oilseed-based scenarios such as Sc 3 could meet the fat demands of maximum adults (95 persons $\text{ha}^{-1} \text{yr}^{-1}$) compared to 9 persons $\text{ha}^{-1} \text{yr}^{-1}$ with Sc 1. The higher Fe demand for 97 persons $\text{ha}^{-1} \text{yr}^{-1}$ could be met with adopting Sc 2 and Sc 3 (66 and 32 persons $\text{ha}^{-1} \text{yr}^{-1}$), compared with Sc 1, which could meet the Fe demand of 7 persons $\text{ha}^{-1} \text{yr}^{-1}$. (Figure 3).

The one-year system findings indicated that the maize-mustard-mung bean system holds significant promise as a substitute for the rice-wheat system in the eastern Indo-Gangetic Plains (EIGP). The maize-mustard-mung bean cropping system contributes significantly to meeting human nutritional needs by delivering a wide range of critical elements. Maize is a significant source of carbohydrates, providing energy for daily activities, and its fiber content helps digestive health through maize mostly used for poultry and livestock feed. Mustard contributes healthy fats, particularly omega-3 and omega-6 fatty acids, along with vitamins A, C, and E, enhancing overall nutrient intake.

Mung beans are packed with protein, essential for muscle development and repair, and also provide fiber, vitamins, and minerals such as iron and magnesium. The combination of these crops creates a balanced dietary profile that can help combat malnutrition and support overall health.

By incorporating these three crops into agricultural systems, communities can improve food security, promote dietary diversity, and ensure access to a well-rounded nutritional foundation, which is particularly important in regions where food sources may be limited.

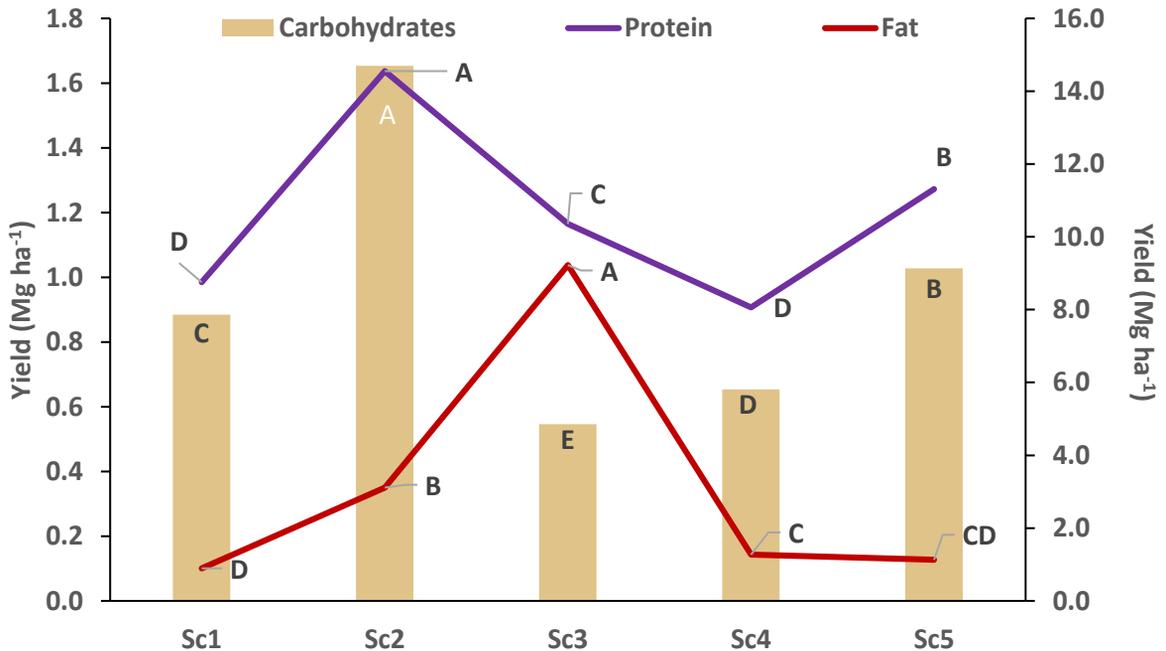


Figure 1: Nutritional yield assessed by cropping pattern for proteins, carbohydrates and fats. The bars are headed by different letters are significantly different, based on Tukey's HSD means.

Figure notes:

Yield of prosomillet not included as not able to harvest due to no germination. Sc1=rice-wheat-fallow system + CT, Sc2=rice-potato-maize system + CT, Sc3=maize-mustard-mung bean system + CA, Sc4=rice-chickpea-prosomillet system +CA, Sc5=rice-wheat-mung bean+ CA

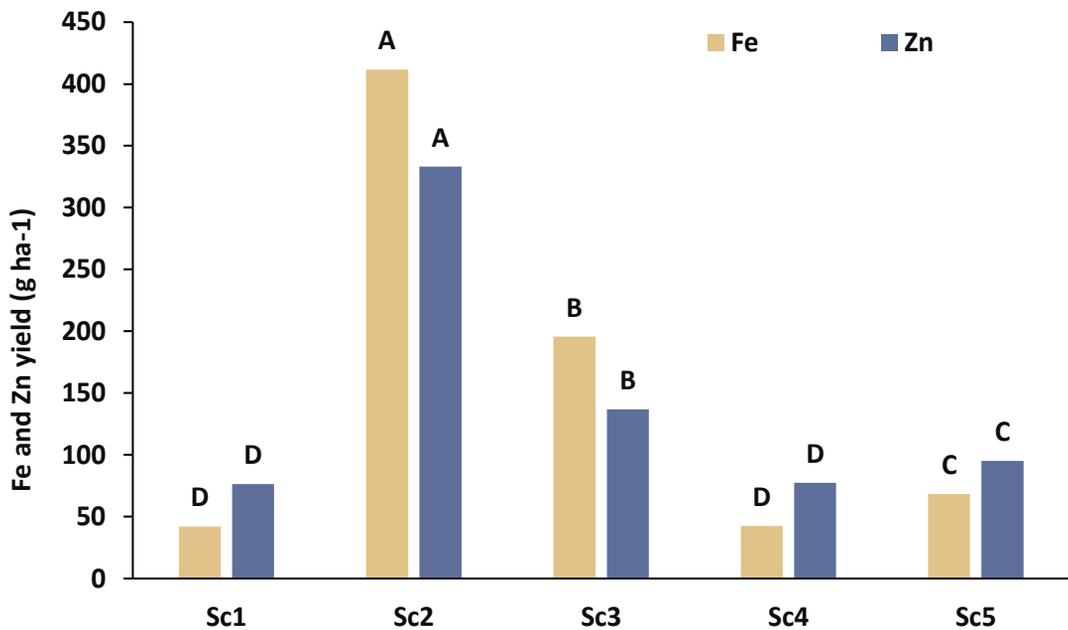


Figure 2: Nutritional yield assessed by cropping pattern for iron (Fe) and zinc (Zn). The bars are headed by different letters are significantly different, based on Tukey's HSD means

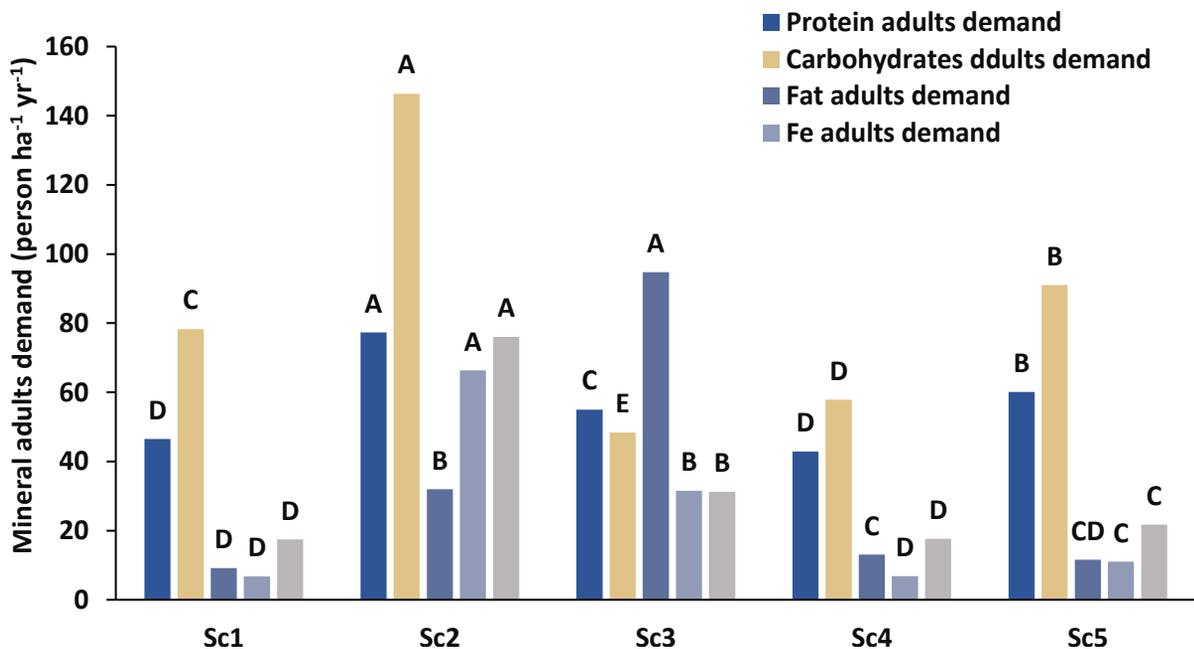


Figure 3: Nutritional Adult demands (person ha⁻¹yr⁻¹) assessed by cropping pattern for proteins, carbohydrates, fats Fe and Zn. The bars are headed by different letters are significantly different, based on Tukey's HSD means.

Figure notes:

Yield of prosomillet not included as not able to harvest due to no germination. Sc1=rice-wheat-fallow system + CT, Sc2=rice-potato-maize system + CT, Sc3=maize-mustard-mung bean system + CA, Sc4=rice-chickpea-prosomillet system +CA, Sc5=rice-wheat-mung bean+ CA

CONCLUSIONS AND RECOMMENDATIONS

Agroecological strategies, including crop diversification and improved agronomic regenerative agricultural practices, can tackle significant challenges in agriculture while improving farm profitability and securing sustainable food with diversified diets and ecological stability for smallholder systems in South Asia. Our study showed that optimizing diversified cropping systems significantly increased nutritional yields: protein by 18-66%, carbohydrates by 16-87%, fat by up to 931%, and iron and zinc yields by 878% to 337%, compared to the existing rice-wheat system.

This enhancement could meet the additional nutritional needs of 9-31 people per hectare per year for protein, 13-68 for carbohydrates, 2-86 for fat, and 4-60 for iron and zinc, compared to conventional farming practices. Therefore, our findings suggest that diversified or intensified crop rotations present a scalable alternative to the rice-wheat system, effectively addressing the pressing challenges of deteriorating natural resources and reducing dependence on imported protein and fats, ultimately contributing to food and nutritional security in a sustainable manner.



Above: Zero tillage wheat field in India; photo: CIMMYT

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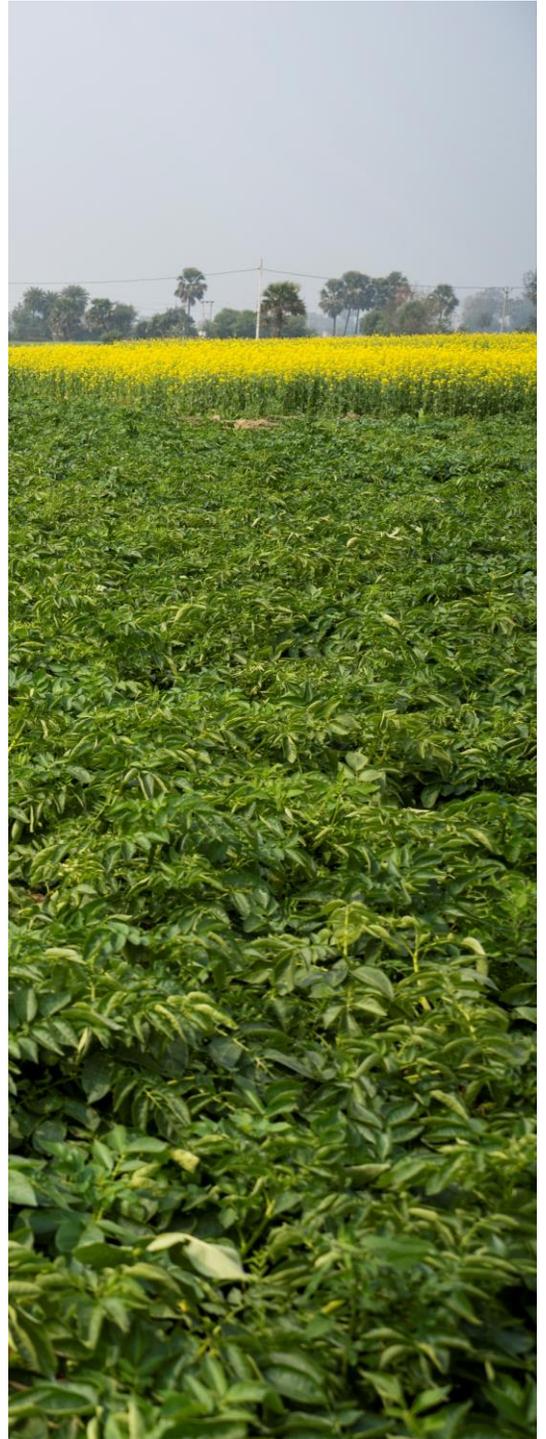
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Above: Potato and mustard field in India; photo: CIMMYT



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ABOUT TAFSSA

TAFSSA (*Transforming Agrifood Systems in South Asia*) is a CGIAR Regional Integrated Initiative to support actions that improve equitable access to sustainable healthy diets, improve farmers' livelihoods and resilience, and conserve land, air, and water resources in South Asia.

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