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Sustainable food production and agriculture's significance for food security in developing nations

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Abstract

India is occasionally considered a growth difficulty because its explosive economic growth in recent decades hasn't been associated with equally rapid gains in nutritional and health conditions. Indian society confronts a significant problem in satisfying basic dietary requirements and reducing demographics whether it hopes to achieve the Goal 2 of the Sustainable Development Agenda (SDG2) eliminating hunger by 2030 stresses from the natural world and one's food. Regarding the initial time, scientists have charted the whole Indian food cord, from farming production to domestic accessibility, in terms of the three essential macronutrients carbohydrates, proteins, along with fatty. Scenario analysis was performed through 2030 and 2050 to understand better the possibility of lowered losses in the food chain and higher agricultural yields to make up for potential food shortagesthis investigation demonstrates that a sizable percentage of the Indian population faces acute shortages of all macronutrients under the country's present self-sufficiency paradigm. While the predicted gaps get larger, rising domestic output alone cannot close the food supply gap, even under ambitious waste reduction and yield predictions. They propose the nation maximize local production while expanding its role in international commerce whether it intends to achieve SDG2.

Keywords: Sustainable Development Goal (SDG2), Agriculture,Food security (FS), Developing nations (DN), Dietary protection (DP).

1. Introduction

The latest statistics from the Indian Food and Agriculture Organization (FAO) indicate that thirteen percent of humanity in developing nations is hungry (Pawlak, and Kołodziejczak,. 2020). Considering that the developments above could potentially make minimal contributions to the global food system over the next two decades, maintaining an uninterrupted supply of food system improvements requires sufficient investment in fundamental investigation and goals have been reinforced with a central premise that "healthy ecosystems are essential for sustainable food production and environmental

sustainability."The purpose of distributing cutting-edge investigations and innovations that confronted pressing issues in food security and environmental development" (Liang, et al., 2020). Scientists contend that proven approaches for sustainable and inclusive agriculture need thorough examinations of the impact produced by both methods (Jagustović, et al., 2019). The adopted Sustainable Development Goals (SDGs) expressly identify the intimate connection between population and the depletion of natural resources, food insecurity, impoverishment, and equitable development, though the earlier Millennium Development Goals (MDGs) achieved consequently informally (Hatab, et al., 2019). Subsequently, people settled on the planet and began farming approximately 12 thousand years ago; feeding an expanding population has been a difficult task. Although the world's population has risen, they still haven't solved this problem (Qualm, 2020). Intensive is embraced among numerous environmentalists who argue that its implementation is needed to protect nature by reducing the spread of agriculture into undeveloped areas (Ickowitz, et al., 2019). These will prove crucial for deciding which agricultural regions have been most competitive and which environments are most vulnerable to their effects. Improved utilization of agricultural land depends on sustainability. Fortunately, a multifaceted investigation is required for complete implementation (Viana, et al., 2022). Considering Rain-fed agriculture provides food security and is the main source of income for about 85% of the population (Kogo, et al., 2021).

Tanumihardjo, et al., 2020 used the SDGs as a framework to elucidate to readers from many areas how the global food and nutrition security may be significantly enhanced by the maize agro-food system.Delgado, et al., (2019) suggested the rising effect Climate change notwithstanding, Sustainable Precision Agriculture and Environment will spearhead the next revolution in precision agriculture and agriculture in general, which might harness prior technology in combination with evaluation of big data. Wang, et al., (2021) provided a more thorough analysis of "circular" substitutes for the linear methods used now, which are essential to enhancing food security and environmental sustainability in the future.Garcia, et al., (2020)solving the issues of assembling interdisciplinary teams to promote environmental stewardship, sustainable food production, and food safety to form a unified nutrition infrastructure.Frongillo, et al., (2019) investigated the probable hedonic adaptation between food insecurity and subjective well-being across nations with the goal of gaining a more nuanced understanding of this connection. A range of strategies for mitigating and adapting to climate change that might lead to increased productivity, more efficient production, and better food security for nine billion people by the year 2050 were assessed by Loboguerrero et al. (2019).Three aspects of India's traditional agriculture were covered by Patel et al. (2020): crop cultivation, biological pest management, and locally available sustainable crop protection methods. Hou, et al., (2021) investigated methods that might cause significant metal infiltration of agricultural land. These procedures include everything from mine excrement discharge into local irrigation systems to the coal-fired power station and incinerator's atmospheric deposition exhaust.

2. Methods

Describing the prevalent agricultural infrastructure across India

To provide a geographical depiction of the Indian food system, from agricultural output to individual food distribution, FAO Food Balance Sheets (FBS) from the FAO statistics archives were used. The FBS offers quantitative information on the production and consumption of food and basic goods along the supply chain. This information is accessible on an international, regional, and national level. The most recent complete set of data, found in the FBS for 2011, was utilized. While some FBS data for 2012 and 2013 is accessible, this remains comprehensive across all commodities and phases in the revenue process. Agricultural output, supply and demand, stock fluctuation, re-sown produce, animal feed,

other non-food uses, and food provided are all quantified in food statements. They contain information on staple foods and products, including grains, roots and tubes, oil seeds and impulses, fruit and vegetables, shellfish, and marine life, including meat and milk. FAO data FBS provides the most comprehensive information for entire commodities system evaluation, although these data are not without their share of uncertainties. Consequently, they can't be flawless, though they provide a good summary of the respective significance of each step in the food's circulation and manufacturing process. This examination shows Information on food loss and waste by supply chain stage is not made available by FBS. Consequently, proportions from the India in FAO articles were used to determine food loss rates, ensuring the data is consistent with other sources. These percentages detail food waste among seven kinds of commodities and five points in the distribution process.Lists the proportion of quantities to be utilized, divided down into product and supply connect steps. The entire nutritional significance throughout every stage of the supply connect was determined by multiplying the whole quantity of commodities according to the FAO elemental dietary aspects. Protein and fat ratios and quantity of energy were determined. Indians have particular fears about protein quality since the food they consume is so dominated by particles, which often have worse digestibility, and amino acid (AA) profiles of plant-based legume substitutes are superior to those of animal products. Thus, protein consumption levels have been adjusted for digestibility, use FAO digestibility ratings to determine protein quality limitations in Indian food more precisely. Using demographic statistics and prospective data, all elements were standardized to average individuals per day availability to maintain consistency and provide a more comprehensive picture of the food chain at the individual supply level. This offers a mean per capita availability number, but it doesn't consider regional differences in the availability of macronutrients. For this reason, we evaluated the anticipated supply distribution for each macronutrient, using the log-normal distribution favored by the FAO and a coefficient variation (CV) factor for India of the measurement. The quantity of food deficits throughout the framework is adequate for estimating the risk of malnutrition, and the developers recognize that people of different ages, genders, and levels of physical activity have distinct nutritional needs. The estimate provided is on the cash normalizing food units to average per individual supply rates is crucial for producing meaningful metrics for wasteful consumption.The predicted consumption of macronutrients was adjusted compared to the dietary guidelines. The "Average Daily Energy Requirement" (ADER) is the average caloric intake required for sustaining an appropriate weight depending on the demographics, occupations, and levels of activity of each distinct demographic; for India's unique socioeconomic, Nutrition needs might differ even among physically comparable people. The long-term national production and availability of macronutrients for Indian food safety so that every person is in danger of failing to receive enough of a certain nutrient, the recommended daily allowance (RDA) is often set In addition to double the typical need. 'Safe' levels are determined through the World Health Organization (WHO) consumption for adults at 0.83 g/kg/d for peptides with a digestible grade of 1. Due to a smaller quantity of animal-based products, and entire proteins in the typical vegetarian’s Indian nutrition, The Indian Institute of Nutrition suggests an increased total protein intake for Indians, at 1 g/kg/d, to meet protein needs. According to typical physiques, the suggested daily protein intake in adult women is 55 grams, while for adult men, it is 60 grams. In light of the curriculum, which takes into protein digestibility, the World Health Organization's (WHO) recommended minimum safe consumption of 0.83g/kg/d translates to around the suggested daily intake of excellent protein corresponds to a 60-kilogram person. Therefore, 50 was used as the RDA in this investigation. The ingestion of vitamins and minerals from food is greatly aided by consuming dietary fats. Micronutrient digestion and utilization may be impaired by a lack of

fat-soluble vitamins, such as vitamins A, D, E, and K. Since insufficient fat consumption may lead to poor food absorption that can worsen the chronic 'hidden hunger concern in India. Additionally, there is no generally accepted number for total fat needs for optimal nutrition. Nonetheless, it is more challenging to meet daily needs for fatty acids estimate than those for energy or protein. Due to limitations in the detail of food accounting information, we cannot precisely quantify the availability of individual fatty acids.

Predicting probable short- and long-term outcomes

It is reducing processing, post-harvest, and dissemination expenses and improving yields of crops are two elements that emerged from our early research as potentially critical in enhancing food supply at the domestic stage. Thus, using these rules as a basis, it has been sketched out potential medium- and long-term futures. It's important to remember that the emphasis in these hypothetical situations is on domestic supply-side initiatives to increase food availability instead of demanding forces relating to consumers' tastes.Describes some fundamental theories for each scenario. Several potential futures for 2030, including the standard procedure for that year, in particular, were investigated.

Case 1: Food loss was expected to be reduced in half throughout the supply process from agriculture to consumption, assuming that people could get everything together regarding harvesting executives, refrigeration for storage, and distribution. That would decrease its deficit rate closer to that of wealthy nations. Subsequently was thought that food wastage would prove to be stable under these conditions.

Case 2: It was anticipated that food chain losses would be cut in half. It was additionally thought that each of the important crops reached 50% due to enhanced agricultural management, farming, and fertilizer applications. The term "attainable yield" refers to the harvest level that may be expected with proper insect, fertilizer, and water utilization.

Case 3: Similar to Possibility two, although it is expected that with increased agricultural yields, it can potentially grow to 75% from 50%.

Case 4: Approximately this instance, scientists assumed that food loss rates would be cut in half across the board, from harvest to processing to delivery. A 50% decrease is more possible in the long term than in the short time since it would need a drastic change in post-harvest management methods, suitable refrigerated storage, and effective transportation.

Case 5: Utilizing a comparable long-term hypothetical 3 assumes a production gap closing to 75% AY across all crop categories.

Case 6: Subsequently was predicted that the disparity in yields would be close to 90% AY across all crop kinds. The entire set of indicators was re-normalized to "under individual a day" while utilizing a projection of India's population perspectives intermediate reproductive assumptions to prepare for the increase in population between 2030 and 2050, respectively.

The expected distribution of crop output was used. It is important to demonstrate that agricultural support systems may maximize food production. This view was supported by FAO statistical data showing a stasis in agricultural expansion over the last decade, concluding that output improvements were accomplished only via intensification in agriculture.

Improvements in crop yields are determined by getting as close as possible to actual farm yields (FY) to potential achievable gains (Ag). FY refers to the typical food a farm produces in a given area. At the same time, "economically AY" describes the amount of food that could

be made if farmers used the most effective methods of water and pest management, fertilizer application, and technology under non-nutrient limiting conditions. Improvements in agricultural output were estimated using published numbers from India that were crop-specific and included percentages of maximum AY realized. All major crop kinds have access to these records includes both the baseline and AY measurements.

Improving nitrogen and control of water are the primary means through which significant yield increases can be accomplished. Throughout this moment's investigation, potential futures have been plotted out depending on the attainment of 50% and 75% AY, respectively. Many crops have already attained these levels and those that haven't usually fall short by 3-5%. Thus achieving 50% AY by 2030 should be theoretically achievable. Reaching 75% AY shortly is a lofty goal since it would need a yield rise of around 20%. Long-term, however, if substantial investments in agriculture management and best practices are realized, AYs of 75% or higher may be possible. Consequently, they estimate the different scenarios through 2050, assuming a yield gap closing of 75% and 90% AY, respectively. The practicality of these assumptions was evaluated by comparing the required growth rates to actual yield growth rates in India's past. The additional analysis elaborates upon the contrast and discusses the suitability of the achievable yield values utilized in this investigation.Productivity consequences are largely reliant on greenhouse gas (GHG) emission scenarios, and the importance of temperature thresholds in total tolerance for crops means that scientists still are unsure whether climate change will affect crop yields. Due to that, this isn't easy to precisely estimate climatic effects in the 2050.Consumption of meat and dairy products across the nation is expected to rise till Mid-century due to rising incomes and changing eating habits. The FAO's projected the average annual consumption of meat has increased from 3.1 to 18.3 kg, a rise of 67 to 110 kgand yogurt consumed annually reflects the estimated level of demand in 2050. Here, we assume that the extra demand for cattle has been satisfied by growing more crops to feed them instead of expanding grazing areas. The prediction was made that the initial distribution of crops for non-food use and reclamation would remain stable, and energy and protein conversion rate metrics for common farm animals types were utilized to calculate the change in nutrition requirements for the feed industry purposes, as well as the proportion of land devoted to different crops continues to be fixed.

3. Results

Current routes in the food system

Figure 1 illustrates the 2011 output and losses in the "field to fork" Indian food chain in terms of energy intake, protein availability, and fatty nutrition routes from agricultural harvest to leftovers. Calorie-wise food paths.

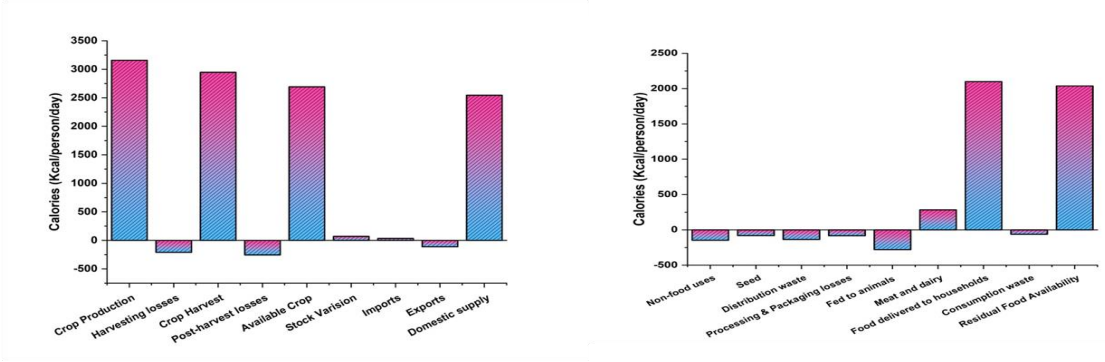

Figure 1: *2011 production and losses in the "field to fork" portion of the Indian food chain. Calorie-wise food paths*

Exports of steel, purchasing, along with stock fluctuation are quite minor and roughly balanced both ingredients and outcomes to the food system. Because of its agricultural approach, this supports the country's objective of being food self-sufficient. **Figure 2** Shows the 'farm to fork' production and waste in India's food chain in 2011. Mechanisms for indigestible protein un food.

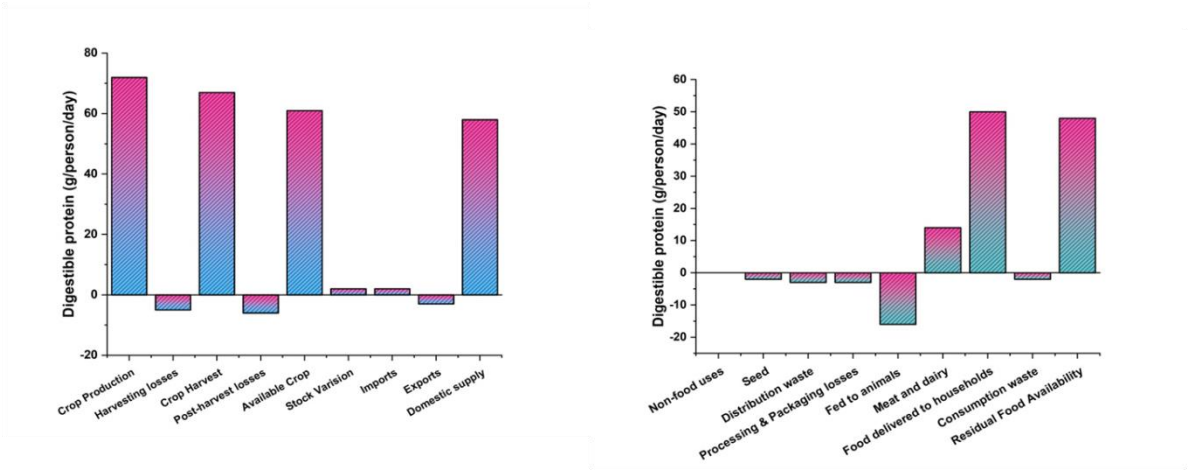

Figure 2:*The 'farm to fork' production and waste in India's food chain in 2011. Food pathways indigestible protein*

The scenarios included discussed here serve to determine the possibility that the identical focus until the year 2050, food independence, will be possible exclusively through waste reduction and crop diversification productivity increases. The per-capita output of energy, a protein that can be digested, and fats in the nation in depicting India. **Figure 3**shows the 'farm to fork' production and waste in India's food chain in 2011fat from the yield of crops to the availability of leftover food.

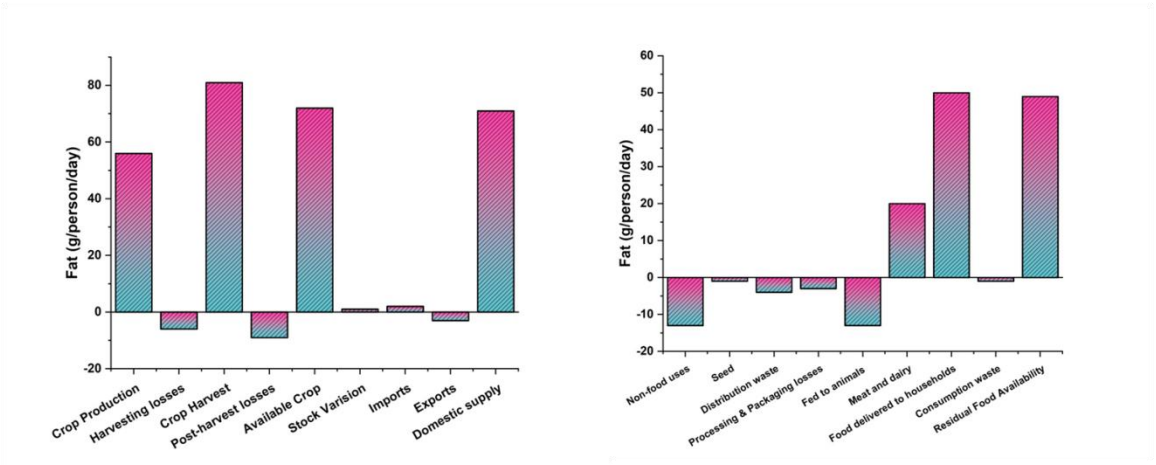

Figure 3:*The 'farm to fork' production and waste in India's food chain in 2011. Food pathways inFat*

Precisely a consequence, the average calorie intake, digested protein consumption, and fat consumed per person per day dropped to 2039, 48, and 49, respectively. Dietary intakes were gathered from the National Sample Survey (NSS) of India twice yearly as determined by national household surveys, which have been used to double-check our top-down supply model. The National Health and Nutrition Examination Survey (NHNES) found that in the 68th Round, people in urban areas consumed an average of 2206 kcal per day, while those in rural regions consumed 2233 kcal per day. Because of this, our top-down study indicates that calorie availability is somewhat lower than the NSS intake statistics, with a high link with fat consumption. **Figure 4** shows Baseline circumstances in the Indian food system in 2050:

output and losses from the farm to the table. Food sources of calories.

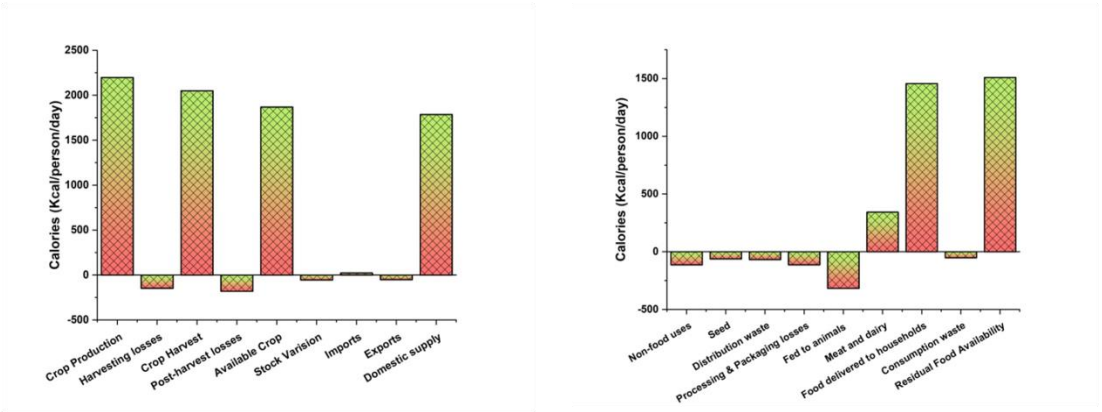

Figure 4:*Baseline circumstances in the Indian food system in 2050: output and losses from the farm to the table. Calorie-based food routes*

The outcomes obtained for digestible protein are not similar to NSS data since NSS data presents total protein without considering quality or digestibility. After adjusting for digestibility, our results suggest that a protein intake is generally enough of 57 g, which is within 5% of NSS consumption estimates**. Figure 5** shows thelosses and gains in the Indian food chain in 2050, given the existing conditions, from farm to fork.Digestible protein;

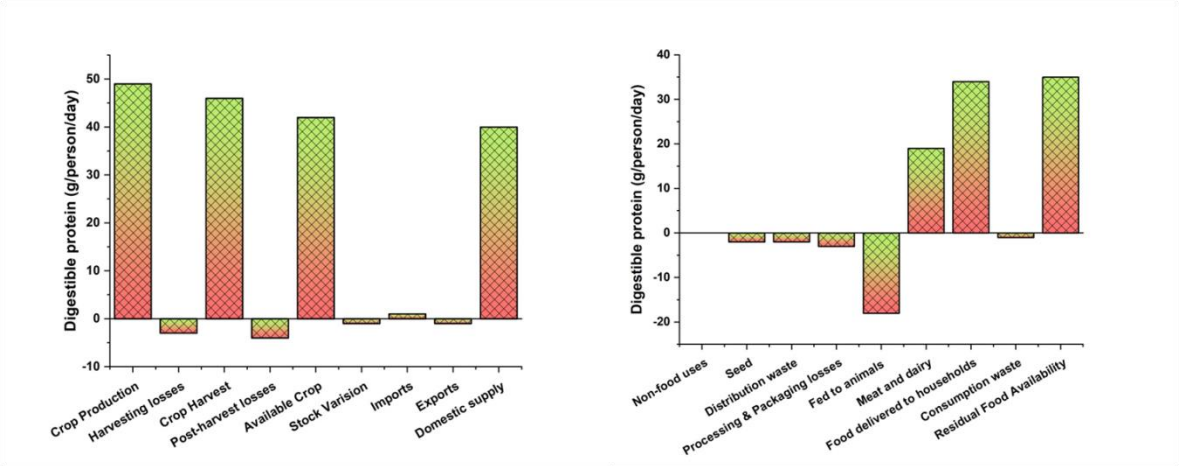

Figure 5:*Losses and gains from farm to fork in the Indian food chain, in 2050 under current circumstances.Digestible protein*

The significant association between the privilege of top-down supply emulation and actual familial consumption assures the use. Regardless of the known limitations in FAO FBS databases, FBS data could potentially be used for high-level food chain analysis, including the one attempted below. The bulk of calorie and protein in the agricultural production and post-harvest waste phases of the food chain in India account for the majority of losses in the food system; losses during the processing and distribution phases are less but still significant. Losses in the consumption phase are controllable. Compared to digestible protein, where the amount lost to alternative non-food applications is minimal, oilseed crop allocation for non-food purposes is the main cause of higher fat losses. India's dependence on animals fed crops for sustenance. It seems rather efficient, with a lower input-to-output ratio than the average of the world's food industries.**Figure 6** shows theBaseline circumstances in the Indian food system in 2050output and losses from the farm to the table.

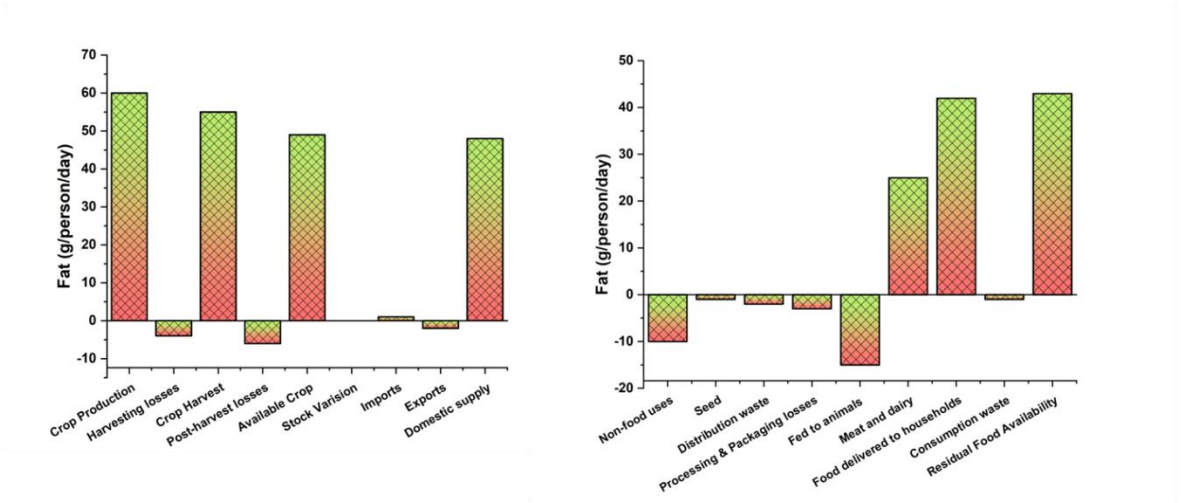

***Figure 6**:Baseline circumstances in the Indian food system in 2050: output and losses of fat from farm to fork*

This constitutes among the few farming methods in which the bulk of the need for animal food is satisfied with crop wastes and waste products, including grazing lands, whose Lacto-vegetarian inclinations tend to favor pasture-fed goats and sheep compared to poultry and other creatures provided feed. The overall per-person average for all the macronutrient supply falls short of their average per capita minimal needs. The population-intake distributions reveal the scope of this problem in India. When average macronutrient availability is considered throughout the population distribution, it is estimated that 66% and 56% of people, respectively, are in danger of not meeting the required energy or protein needs. Table 1 depicts the Mean macronutrient availability 2030 under various scenarios for waste and yield.

Table 1: Average availability of macronutrients in 2030 under various waste and yield scenarios

Scenario	Proteins accessibility on a daily schedule averaged as gpppd	Standard energy content; kcal/pound/day	Average daily fat intake; gpppd
2011 Baseline Scenario	49 (57%)	2040 (67%)	50
Scenario 1 (halving food losses)	43 (76%)	1755 (85%)	44
Scenario 3 (achieving 75% AY)	43 (76%)	1832 (81%)	47
Recommended Daily Intake (RDA)	51	2270	-
2030 Baseline Scenario	40 (84%)	1666 (90%)	41
Scenario 2 (achieving 50% AY)	41 (82%)	1676 (89%)	42

Potential future pathways

The findings compared to hypothetical evaluations for possible decreases in food waste and increases in agricultural yields are compiled. As we have assumed no change in the differences in income and nutrition, the CV in the distribution has remained constant. In all cases, the availability of fat, digestible protein, and average daily caloric intake are lower

than the 2011 baseline. Wastage or increased yieldsfall short of keeping up with population increase until 2030. Distribution of availability reveals much larger potential malnourishment at existing levels of food disparity. In all circumstances, most people risk not having enough protein and calories. Even if production and efficiency increases are considerable and ambitious, this reflects acute malnutrition across India in 2030. India's chances of achieving the SDG2 goal of ending world hunger by 2030 would be very slim under these circumstances.

Through 2050, the availability of residential macronutrients in India may be severely impacted due to the expected population expansion plus any potential climate change effects on agricultural output. Assuming food productivity increases stay constant at present our baseline 2050 scenario illustrates these possible effects. Throughout Fig. 2A–2C, the complete distribution paths are demonstrated. The average provision per person would be inadequate, even at the top of the supply chain, to fulfill the demands for every macronutrient. This research emphasizes how crucial it is to also achieve notable increases in agricultural production at the top of the supply chain, even as reducing food system losses is crucial for improving availability for households. Supplementary Fig. 1A–1C not only presents baseline distributions but also illustrates the impact of these factors on availability at the household level in three different scenarios and our baseline 2050 scenario. As directed, more than 80% of the population might consume less protein and energy than is necessary in 2050, even in the case of case 1. Projected levels of malnourishment wouldn't reach present levels until there were huge yield improvements to 90% AY. 62% and 56% of the population respectively, would still be in danger of not consuming enough protein and calories, according to recommendations. Table 2 depicts the Comparing 2050 means nutritional accessibility under various waste and production assumptions.

Table 2: Comparing 2050 means nutritional accessibility under various waste and production assumptions

Scenario	**Proteins accessibility on a regular schedule averaged to gpppd**	**Standard energy content; kcal/pound/day**	**The standard deviation of fat intake; gpppd**
Baseline 2050	34 (96%)	1406 (98%)	43
Scenario 2 (achieving 75% AY)	41 (82%)	1722 (87%)	58
Recommended Daily Intake (RDA)	51	2270	-
Case 1 (reducing food loss by half)	40 (84%)	1662 (90%)	52
case 3 (achieving 90% AY)	49 (57%)	2100 (63%)	67

4. Conclusion

To facilitate food security in emerging nations, sustainable agriculture, and food production are essential. These economies may boost agricultural output, simultaneously reducing the detrimental effects on their ecosystems by using ecologically friendly methods, including the practice of agro ecology, precision farming, and water conservation measures. Additionally, strengthening communal resilience and giving small-scale farmers more support might make populations less susceptible to food crises and outside shocks. Through creating employment possibilities and protecting the environment for future generations, adopting sustainable practices also promotes long-term economic growth. Prioritizing sustainable food production is not only important but also a means of ensuring food security and promoting a better, more equitable future for all people in developing countries to deal with the problems caused by fast-expanding populations, including worldwide warming.

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