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COMMENTARY

A Farming System Model to Leverage Agriculture for Nutritional Outcomes

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Abstract Agriculture is the primary livelihood of a majority of the population in South Asia. The region also houses a large population of undernourished people. The farming system for nutrition (FSN) model envisages developing and demonstrating a sustainable framework of farming to improve nutritional outcomes that can be used for upscaling and wider adoption. Agricultural intervention and farming systems research in India has been largely focused on enhancing production, productivity and profitability of crop and animal resources without much emphasis on better nutritional outcomes. The FSN model has been conceptualized to develop location-specific inclusive models to address the nutritional needs of farm and non-farm families based on their resource endowments and surrounding environment. The main components of the model are as follows: (1) survey to identify the major nutritional problems, (2) design suitable agricultural interventions to address the problems, (3) include specific nutritional criteria in the design, (4) improve small farm productivity and profitability, (5) undertake nutrition awareness programmes and (6) introduce monitoring systems for assessing impact on nutrition outcomes. The objective is to demonstrate feasibility of nutrition-sensitive agriculture. The proposed model is being tested in two select locations to demonstrate improvement in nutrition status through improved agricultural production system, dietary diversification, income enhancement, greater nutrition awareness and changed behaviour patterns, to be evaluated through a set of objective indicators.

Keywords Malnutrition · Farming system for nutrition · Dietary diversity · Nutrition awareness

Abbreviations
DMLT: Diploma in Medical Laboratory Technology; FAO: Food and Agriculture Organization of the United Nations; FFS: Farmer field school; FGD: Focus group discussion; FLD: Field level demonstration; FSN: Farming System for Nutrition; GDP: Gross domestic product; ICT: Information and communication technology; IEC: Information, education and communication; IFPRI: International Food Policy Research Institute; KAP: Knowledge, attitude, practice; PRA: Participatory rural appraisal; UNICEF: United Nations Children's Fund; WASH: Water, sanitation and hygiene; WHO: World Health Organization;

Introduction

India registered remarkable economic growth during the first decade of this millennium. Ironically, during this period, a vast section of population remained undernourished (Box 1). Levels of child underweight in India at 43 per cent are twice the average level of 21 per cent reported in sub-Saharan Africa; and stunting at 48 per cent is 8 per cent higher than that reported in sub-Saharan Africa [7, 23].

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Box 1 Highlights from Report of National Family Health Survey (NFHS)-3

Wasting is quite a serious problem in India, affecting 20 % of children under 5 years of age
48 % children under 5 years of age are stunted and 43 % are underweight; 24 % are severely stunted and 16 % are severely underweight
Almost 70 % children of age group 6–59 months are anaemic, including 40 % who are moderately anaemic and 3 % who are severely anaemic. The prevalence of anaemia does not vary by sex of the child
55 % of women and 24 % of men are anaemic
More than one-third of women (36 %) and men (34 %) of age group 15–49 years have a body mass index (BMI) below 18.5 indicating chronic nutritional deficiency, including 16 % of women and 9 % of men who are moderately to severely undernourished
In general, women's food consumption is less balanced than that of men. 55 % of women, compared with 67 % of men, consume milk or curd weekly. Only 40 % of women, compared with 47 % of men, consume fruits weekly; 32 % of women, compared with 41 % of men, consume eggs weekly; and 35 % of women, compared with 41 % of men, consume fish or chicken/meat weekly

Source Government of India [7]

Malnutrition in all its forms imposes unacceptably high burden on society and contributed one-third to one half of child deaths [7]; the annual economic losses associated with malnutrition have been estimated at 3 per cent of India's Gross domestic product (GDP) [18].

Agricultural Growth and Food Security

Growth in agricultural productivity has the potential to contribute to better nutrition through raising incomes, especially in countries like India where this sector accounts for 14 % share in GDP and employment of 58 % of the total population [8]. Agricultural interventions in India from the 1960s till the early 1990s were focused on increasing food grain production and productivity to attain self-sufficiency and address more important issues like food shortage and hunger. Introduction of high-yielding varieties, greater access to fertilizers, irrigation water, farm equipments, pest control, technology transfer and minimum support price were a part of the package that led to the green revolution in the late 1960s [20]. Growth in agricultural productivity and production remains crucial. Demand for food grains is expected to increase with the enactment of the National Food Security Act by the Government of India in late 2013, ensuring a legal right to food.

The Gap

Experience has, however shown that increasing food production alone cannot address the issue of malnutrition, unless there is a nutrition focus and the poorest have access to a source of diversified and nutritious foods. Food Security encompasses 'Availability', 'Accessibility' and 'Utilization' which includes 'absorption' and bioavailability of food making it inclusive of 'Nutrition Security' [17]. Beyond staple foods, a healthy diet means a diversified food basket containing balanced foods providing adequate amounts of energy, fat, protein and micronutrients. Agricultural interventions in the development paradigm need to be more *nutrition-sensitive*, with a greater focus on nutrient-dense foods with high levels of bioavailability, i.e. the proportion of micronutrients capable of being absorbed by the body. The thrust on increasing production and productivity enabled India to address calorie hunger, but hidden hunger caused by micronutrient deficiencies is widespread. Given the large percentage of population dependent on agriculture, the problem of malnutrition can be better addressed through a farming system for nutrition (FSN) approach.

It may be noted that internationally also there is a drive to end the scourge of malnutrition. The United Nations launched a zero-hunger initiative in 2012 with a target for eliminating hunger, malnutrition and food insecurity by 2025 (Box 2).

The relationship between agricultural production, consumption patterns and nutritional outcomes are not direct but complex, distant and often weak [1]. Studies across the globe clearly highlight the fact that changes in income alone do not immediately translate into changes in consumption pattern and dietary diversity to improve nutritional status. The Tackling the Agriculture–Nutrition Disconnect in India (TANDI) initiative identified seven core pathways between agriculture and nutrition [6] adding two more from the gender perspective to the five identified by the World Bank [25]. The focal theme of FAO's recent report on State of Food and Agriculture is 'Food Systems for Better Nutrition' [4]. Agricultural projects that utilize micronutrient-rich plant varieties have shown high potential for improving nutritional well-being [10, 12]. Reviews by Berti et al. [2] and Masset et al. [13] found no conclusive evidence of the effects of agricultural interventions on nutritional status in general, but did find positive impacts of selective interventions like home gardening and biofortification. Gulati et al. [9] found that improving agricultural performance can have a positive impact on nutritional outcomes.

The role of mediating factors is also crucial. Malnutrition is a multidimensional problem that requires multisectoral interventions. Several reviews concluded that projects having clear effects on improved dietary intake or

Box 2 Zero Hunger challenge launched by the United Nations

The five pillars of the zero hunger challenge launched by the UN Secretary General at the Rio + 20 conference on sustainable development at Rio de Janeiro in June 2012 are

1. 100 % access to adequate food all year round
2. Zero stunted children <2 years of age
3. 100 % increase in small holder productivity and income
4. All food systems to be sustainable and
5. Zero loss or waste of food

Source United Nations [22]

Box 3 The Indian Hunger Crisis

Farm families constitute the majority of India's population. A majority of small and marginal farm families as well as landless labourers suffer from undernutrition, because of inadequate income. Thus, we have to deal with three kinds of hunger if we are to achieve food and nutrition security for all. First, we have to help farm families overcome undernutrition as a result of deficiency in calorie. Second, protein hunger is becoming serious due to the inadequate consumption of pulses and milk (in the case of vegetarians) and eggs, fish and meat (in the case of non-vegetarians). Third, there is widespread hidden hunger caused by the deficiency of micronutrients like iron, iodine, zinc, vitamin A, vitamin B12, etc., in the diet

Source Swaminathan [21]

nutritional status were likely to be those in which either women played a critical role in the intervention or the intervention included a nutrition counselling component [11, 16, 25]. A complex interaction of food intake, water quality, care practices, disease burdens, sanitation and health services, as well as the deeper social, economic and political processes that drive these intermediate outcomes impact on nutrition [24]. Overall, however, one finds a sense of urgency and initiative to understand and demonstrate efficacy of pro-nutrition agriculture interventions [3, 5, 15, 26, 27].

Approach to Improve the Nutritional Status

Nutrition-Sensitive Agriculture

The FSN model envisages the introduction of 'agricultural remedies for the nutritional maladies' prevailing in an area, through mainstreaming of nutritional criteria in the selection of the components of a farming system involving crops, farm animals and where feasible, fish. The approach demands integration with enabling non-farm factors like hygiene and sanitation to improve absorption and bio-availability, as well as focus on differential human nutritional needs across gender and age groups. The overarching aim of the FSN model is to demonstrate sustainable farming systems to improve nutritional outcomes at household level that can be replicated and upscaled. It aims to address the nutritional needs of farm and non-farm families based on their personal assets, market conditions and community preferences. The study will examine the effectiveness of multisectoral approaches for improved farming system based on both food (crop and animal) and non-food (sanitation, water, access to resources, nutrition education and dietary diversity) factors.

The hypothesis underlying the FSN model is as follows—specially designed agricultural interventions with nutrition focus can enhance agricultural productivity and farm incomes, lead to more diversified and nutritive dietary pattern and result in better nutritional outcomes. In essence, the FSN model seeks to understand whether and how agricultural interventions can generate nutritional impacts in general and specifically explore the scope of the approach to improve the nutritional status of malnourished population (Box 3).

Major Components of the FSN Model

The FSN model has six major, equally important components [19]:

1. Survey the area to identify the main nutritional problems: baseline surveys to understand the prevailing socio-economic, agriculture and nutrition situation.
2. Identify suitable agricultural solutions to address the problems (crop–livestock integration, cultivation of pulses and biofortified crops): from the baseline survey, available secondary data and frontline demonstrations on farming practices, design most suitable agricultural remedies in consultation with the community, giving weightage to personal assets, market conditions and community preferences.
3. Include specific nutritional criteria in the design of the farming system: demonstrate a sustainable model of farming with nutrition focus, with the express purpose of improving nutrition.

Table 1 List of the surveys

Sl.	Particulars	Purpose	To be administered on
1.	Preliminary household survey to capture socio-economic, agriculture and consumption pattern	Understand existing profile of the study area for designing protocol	All households
2.	Detailed baseline household survey on demography, agriculture and socio-economic aspects	To document the baseline profile of households	All households
3.	Baseline consumption survey in the first year (3 rounds)	To understand seasonal variations in consumption at household level	All households
4.	Baseline income and expenditure survey	To capture different sources of income and production and consumption expenditure	All households
5.	Baseline employment survey (including 3 rounds of migration survey in the first year)	Profiling the current occupation and migration pattern	All households
6.	Baseline cost of cultivation survey	To collect information on cost of cultivation of major crops	Subsample across all categories of landed households
7.	Baseline time use survey	To capture time spent by both men and women on farm, non-farm and household activities	Subsample across all categories of households
8.	Baseline survey on access to resources and decision making	To collect information on gender roles and responsibilities	Subsample across all categories of households
9.	Baseline health and nutrition survey (anthropometric and history of morbidity)	To collect information on height, weight and morbidity (preceding fortnight) of all members	All individuals from each of the households
10.	Baseline intra-household dietary survey (24-h recall)	To document existing dietary pattern within the household	Subsample across all categories of households
11.	Collection of blood samples for biochemical analysis	To assess level of iron and vitamin A deficiency	All children 1–5 years, adolescent girls 12–17 years and women 18–45 years
12.	Midterm process evaluation	To assess the acceptability of intervention strategies, compliance, success/failure, identify bottlenecks	Sample households
13.	End line surveys (repeat of nos. 2–11)	To assess impact of the project	As per nos. 2–11

4. Improve small farm productivity and profitability in order to enhance cash income: integrate income enhancement of small farms with the production of nutritious crops (both natural and biofortified) integrated with home gardening, livestock (ruminants, poultry, fisheries) and agroforestry.
5. Nutrition awareness: undertake nutrition awareness/literacy programmes at the levels of the household, community and institutions.
6. Introduce monitoring systems for process evaluation based on well-defined and measurable criteria; develop indicators to assess impact on nutrition status; end line surveys to capture the change.

An important aspect of generating evidence is to compare the impact of interventions within and across villages, involving baseline and end line surveys of the agricultural production system and nutrition status. A few villages in a region are to be excluded from FSN intervention (non-FSN villages), while all the households in the remaining villages are introduced to FSN.

The list of the various surveys is given in Table 1.

Baseline Survey

The objective of baseline surveys is to document the current socio-economic status, farming practices, production and productivity, nutrition status and the sourcing pattern of food items as this is one of the major factors influencing consumption. The main instruments for data collection are different sets of suitably designed structured questionnaires for the village and household and focus group discussions (FGDs).

- *Village Questionnaire*: the village questionnaire has been designed to collect information on food production and consumption systems' availability, access to various natural resources and access to government facilities, health, transport and communication facilities.
- *Household Questionnaire*: different sets of household questionnaire have been designed to capture the demographic and socio-economic profile of the households, occupational pattern and nutrition status. These are crucial to design and estimate the impact of FSN based on a set of identified indicators.

- *Focus group discussions (FGD)*: capture the following at baseline, midterm and end line levels: (a) level of nutrition knowledge (balanced diet, cooking practices, etc.), (b) childcare practices, (c) access to water, sanitation and hygiene (WASH), (d) access to entitlements and government extension services, (e) qualitative aspects of gender roles in access to resources and decision making, (f) any other relevant issues that come up during the implementation of the programme.

Intervention Design and Strategy

Food systems determine the quantity, quality, diversity and nutritional content of the foods available for consumption which are either produced or bought by the households. FSN intervention strategy envisages addressing the issues related to accessibility, availability and affordability of nutritious foods to households and their absorption. It aims to address all the major nutritional maladies, i.e. calorie deprivation, protein deficiency and hidden hunger (micronutrient deficiency, e.g. iron, vitamin A, vitamin B12, zinc, iodine) through farm sector interventions including introduction of biofortified crops. Complementing these will be non-farm and non-food strategies—nutrition awareness and literacy, and WASH to address absorption. Throughout the process, three core crosscuts of gender, fragility and systems of innovation will be studied and addressed. Strategies for interventions with targeted population and the tools are described in Table 2.

Measuring Impact

The farm sector intervention consists of three components: (1) crop (A), (2) livestock (B) and (3) vegetables and fruits (C). Based on household characteristics, households are expected to adopt either all three components ('ABC') or any two ('AB/AC/BC') or just one ('A/B/C'). The non-farm sector intervention is targeted at all households in the FSN villages. The comparison will be twofold:

- Comparing the FSN and non-FSN villages based on the aggregate FSN intervention, keeping the common features of the households (X variables) as fixed, the impact of the intervention will be measured on the adoption of FSN at aggregate level (irrespective of adoption of one, two or three components of intervention) and not at the sub-components level.
- The households within the FSN villages would be compared across the three aspects ('A/B/C', 'AB/AC/BC' and 'ABC' models) of interventions using suitable statistical techniques to account for the non-inclusion/adoption by households across these components with due importance to social, economic and demographic variables.

Within FSN villages, for assessing the potential impacts of the different groups of FSN interventions mentioned above, a sample of households would be drawn from each of the subgroups of intervention. The variables that could potentially be influenced by FSN will be considered for comparisons and are indicated below:

(a) Per capita monthly consumption expenditure of the household and its share in total household income.
(b) Sourcing of food items at the household level (home grown, market and public distribution system) to find out their dependence and how it changes after intervention.
(c) Dietary diversification index based on different measures including food composition based on macro- and micro-nutrients.
(d) Measure of nutritional status based on anthropometric measures and biochemical parameters for select population—children, adolescent girls and women.
(e) Intra-household consumption patterns and an index of inequality in household consumption or any related measure.

Following approaches are to be used for evaluating the changes:

- *Difference in differences method (DiD)*: this statistical approach would help us in ascertaining the average changes in nutrition-related measures over time in the FSN villages in comparison with the non-FSN villages. The nutrition outcome indicators for children and women would be focusing on nutritional anthropometry, haemoglobin and serum vitamin A levels and on intra-household distribution for changes in food intakes and dietary diversity. The baseline and end line surveys would serve as the two time-points for comparison.
- *Multiple measurement approach*: this approach, as suggested in McKenzie, 2011 [14], when impacts of an outcome are correlated, will include analysis of the household production and consumption pattern, employment scenario including migration and morbidity where, instead of a single baseline and end line, there would be multiple measurements during the entire project phase so as to follow a trajectory of impacts.

The steps envisaged in the intervention design are primarily focused on a participatory approach and Farmer field school (FFS) technique. The schematic diagram of the steps is given in Table 3.

Table 2 Intervention strategies, target population and tools

Interventions	Target population	Tools, strategies and supporting technologies
A. Targeted interventions: farm sector		
1. Cropping system	Farmers with operational landholdings	Participatory Rural Appraisal (PRA) and Focus Group Discussion (FGD)
Intervention (crop calendar, crop types and technology) in existing cropping system to enhance farm output and input usage efficiency		Front Line Demonstration (FLD)
		Farmer Field School (FFS) technique
Introduction of nutrient-dense biofortified crops in the crop calendar (for example, iron-rich sorghum and vitamin A-rich orange fleshed sweet potato)		
Introduction and popularization of locally grown naturally fortified and locally consumed nutritious foods (greens, *aml*a, *moringa*, tubers, etc.)		
2. Livestock system	Farmers with experience of raising livestock with special preference to the most vulnerable group without operational landholdings	PRA and FGD
Intervention in scientific goat rearing, backyard poultry and fisheries for income enhancement and consumption		Awareness generation about Feed and Breed Improvement Program (FBIP)
		Creation of fodder and pasture cafeteria on farmers' plot
Improved silvipastoral system (forestry + pasture + livestock) for optimizing the land use pattern		
3. Vegetables and fruits	Farmers with homestead land and experience of growing vegetables and fruits	PRA and FGD
Establishing nutri-garden in backyard of each farm family to promote vegetables and fruits rich in iron and vitamins A and C		FLD
		FFS technique
		Scientific crop/nutri-garden architecture
B. General interventions: farm and non-farm sector		
1. Nutrition literacy and awareness at various levels	Level-1: Household	Content development on nutrition
	Level-2: Community	Information and Communication Technology (ICT)
	Level-3: Institution	
2. Agronomic best practices	All farm households, on all field crops, vegetables and fruits	Agriculture extension services
		Training and visit (T and V)
		Lab to land and land to Lab
3. Introduction of low-cost technology (e.g. fertilizer use efficiency, new varieties/crops, water use efficiency)	All farm households	Fertilizer deep placement technology (FDP)
		High density planting system (HDPS)
		Small agriculture implements
4. Livestock health care services (e.g. health check-up camp, de-worming, vaccination)	All households having animal resources	Vaccination/de-worming/artificial insemination techniques
5. Improved feed and fodder	All farm households	Fodder silage technology
6. WASH	All households	Awareness generation through drama, film shows and ICT tools
7. Access to resources (e.g. credit, community land, water)	All households	Awareness generation using mass media
8. Value chain facilitation	All households	Value chain analysis
		Nutrition entry and exit point
9. Capacity strengthening	All households	Mapping strengths and weaknesses
		Drawing capacity building chart for each group
10. Inter-sectoral linkages and ecosystem	All households	Crop–livestock–pastoral ecosystem and the technology thereto

Table 2 continued

Interventions	Target population	Tools, strategies and supporting technologies
C. Addressing crosscuts		
1. Gender		
(a) Design and implement pro-women agricultural interventions		
(b) Sensitize the members (men and women) of the households on fair, differentiated need-based and equitable intra-household food sharing and time use with IEC tools		
2. Fragility: understand, document the levels of ecological fragility; explore and introduce measures to alleviate them		
3. Innovation systems: document at all levels of implementation of FSN and disseminate		

Table 3 Steps in FSN intervention design

Steps	Particulars
Step-1	Baseline survey of households in the FSN and non-FSN villages to understand the existing agricultural systems and socio-economic condition, including time use pattern. Identification of key informants and village institutions
Step-2	Constitute technology platform for interaction with academics, research institutions and stakeholders platform with government line department, local self-government, men and women farmers and landless households and NGOs, to leverage collaborations for both feedback and outreach
Step-3	Demonstration and FFS on crop, livestock and horticultural systems to showcase scientific and technological advancement in farming
Step-4	Identify the nutritional disorders/deficiencies prevailing in the area (both protein–energy malnutrition and hidden hunger) through a range of surveys. Collection of household level anthropometric and gender disaggregated information
Step-5	Focus group discussions to understand nutrition sensitivity among the population, gender roles and decision making in access to resources, cultivation and use of the produce
Step-6	Based on the agro-ecological and socio-economic conditions, design farming systems that can provide agricultural remedies to the prevailing nutritional maladies
Step-7	Develop, in association with the farm families, a nutrition-smart farming system. Major components of such a farming system will be: crop–livestock integration—large and small ruminants, poultry, fish, vegetables and fruits, trees, etc.
Step-8	Content development for dissemination of improved agriculture practices, exposure trips and training programmes
Step-9	Content development for nutrition education/literacy for all levels, to improve awareness on dietary diversity, storage and cooking practices, health and hygiene, etc.
Step-10	Integrate the relevant existing government programmes and entitlements with the intervention to achieve greater impact

Measurement Indicators

The FSN model study protocol described above seeks to document and understand whether and how agricultural interventions can result in nutritional impact, particularly among children under five, adolescent girls and women.

Measurement indicators for farm, non-farm and nutrition intervention and crosscuts (gender, fragility and systems of innovation) have been developed through concerted engagement and consultation with experts from the fields of agriculture, nutrition, health, economics and gender, to suit the aims and objectives of the intervention study. The details of the output, outcome and the impact indicators are given in Table 4. They have been divided into categories of farm, non-farm, nutrition, capacity strengthening and research uptake, with indicators also for the three crosscuts, viz., gender, fragility and systems of innovation.

Feasibility Study

A feasibility study of the FSN model described above is currently underway at two locations in India. This study could be among the first to design a system-wide farming intervention to enhance nutritional status of those primarily

Table 4 Measurement indicators of FSN

Output indicators	Outcome indicators	Impact indicators
1. Farm indicators		
Yield/production/farm output	Change in income	Purchasing power of households
	Production efficiency	Adoption of best practices
	Cropping intensity and crop–livestock silvipastoral rotation	Farm diversification
Access to resources by women and men farmers	Change in income and time use pattern	Resource allocation and empowerment
Adoption of new techniques/technology by farmers (women and men)	Reduction in drudgery	Changes in lifestyle
	Change in time use pattern	
Soil and land management techniques	Change in land use pattern	Adoption of 3 Ps (practices, packages and performance)
	Biomass yield	
Crop coverage and silvipastoral area	Change in livestock nutrition	Improvement in ecosystem
Ground water recharge	Change in irrigated area	Adoption of new crops
2. Non-farm indicators		
Water quality	Change in morbidity	Improvement in health status
Penetration of nutrition literacy among women and men	KAP (knowledge, attitude, practice)	Behaviour change
	Informed decision making	
WASH	Change in morbidity and time use pattern	Health status and drudgery reduction
No. of IEC materials on agriculture and nutrition	KAP	Behaviour change
3. Nutrition indicators		
Consumption of various foods as well as macro- and micronutrient intakes compared to RDI/RDA	Change in nutritional status	Dietary diversification; nutritional adequacy
	(a) Anthropometric indices	
	(b) Iron deficiency	
	(c) Vitamin A status	
	(d)Seasonal variation	
4. Capacity building indicators		
Training and exposure visits	KAP	Behaviour change
FFS	KAP	Adoption of new cropping system and technology
5. Research uptake indicators		
Evidence dissemination	Sensitization of stakeholders and policy elite (both gender and fragility)	Policy change; upscaling and replication
Demand for research	More research evidence in public domain	Opening of new areas of research

RDI/RDA Recommended dietary intake/recommended dietary allowance as per norms of the Indian Council of Medical Research (ICMR)

1. The indicators on gender sensitivity (sex-segregated and gender-differentiated data) are incorporated in the outcome and impact indicators

2. The fragility indicators are divided into three major areas of concern: ecological, socio-economic and nutritional. Socio-economic and nutritional fragility are addressed in the main indicator definition; ecological fragility emanates from three major sources: (a) land and soil, (b) water and (c) vegetation, which eventually depends on key climatic parameters

3. Systems of innovation will be studied and documented as and when observed

involved in agriculture and allied activities. The interventions under FSN are designed to integrate farm income enhancement, production of nutritious crops (both natural and biofortified), family-/community-managed home gardens, livestock, poultry and fisheries production, to address the needs of farm families based on the nutritional requirements, asset ownership, market conditions and community perceptions and preferences. The common and differentiated needs of nutrition at individual/household level have also been considered in designing the study in two distinct agro-ecological regions of the country dominated by food and non-food crops and with different consumption patterns. The proposed design of the feasibility study aims to assess the potential impacts of FSN on human nutrition by selecting a group of villages in the two different agro-climatic regions of rural India. Among the

selected villages, a few villages in each region are excluded from FSN intervention, while all the households in the remaining villages are introduced to FSN. The FSN and non-FSN villages within a given agro-climatic region are similar in their agricultural practices, access to natural resources like water, grazing land and forest. This allows the possibility for drawing comparisons of changes in nutritional outcomes between the FSN and non-FSN villages at the end of study period.

Study Locations

The FSN study is being conducted in Wardha District in the Vidarbha region of Maharashtra and Koraput District of Odisha. The locations were purposively selected due to their character contrast in agro-climatic and socio-economic condition, landholding pattern, agricultural practices and consumption pattern. Although agro-ecologically the two study intervention locations are different, both of them are characterized by rain-fed farming and high levels of malnutrition and figure in the list for coverage under the multisectoral programme for high-burden districts announced by the government of India.

The Government of India's census data of 2011 (www.censusindia.gov.in) provided preliminary socio-demographic information on the study region, based on which a set of villages were identified. This was followed by a preliminary survey of households in these villages and FGDs with them to ascertain whether the nature of information gathered from a secondary source like the census was validated at the ground level. This also enabled a better understanding of the ground realities and in assigning the FSN and non-FSN villages such that the non-FSN villages are located at a distance from the FSN villages to avoid any contamination of the proposed FSN intervention between the two regions. Five villages from two blocks of Wardha District (556 households with population of 2,254) and seven villages from one block of Koraput District (663 households with population of 2,865) have been identified as FSN villages for the study. The non-FSN villages comprise of three villages with 266 households and a population of 1,033 in Wardha District and four villages with 265 households and a population of 1,120 in Koraput District.

Analysis of data from preliminary survey of the study villages reveals that average landholding size is about 2 ha or 5 acres in Wardha District as against 2 acres in Koraput District; cotton and soybean dominate the cropping pattern in Wardha during *kharif* with pigeon pea as an intercrop; wheat and chickpea are grown in *rabi* subject to water availability. Paddy is the major crop in Koraput; finger millets and pulses are also cultivated. Wheat and rice are the staple cereal foods followed by sorghum, consumed by all categories of households in Wardha. Pigeon pea is the most consumed pulse; most households consume milk and green leafy vegetables on daily basis. In Koraput, rice and finger millet are the main staple cereals and lentil the major pulse; some wild food like bamboo shoots is also commonly consumed. Milk consumption is rare, but eggs are consumed periodically.

The study is designed to cover all the households in the FSN villages with more than one intervention per household, depending largely on the landholding of the households. The mapping, listing and nutrition survey are being carried out using tailor-made questionnaires that take into account all dimensions of food production and intended gender and nutritional outcomes. Field investigator teams were recruited and trained in the conduct of the different surveys and nutrition status assessment methods prior to commencement of the surveys.

Technology and stakeholder platforms have been constituted at each site to advice and guide the project teams on aspects of design and implementation, and leverage partnerships to maximize the benefits. The technology platform consists of research institutes and agriculture and veterinary universities—'knowledge partners' who provide technical guidance and support; the stakeholder platform comprises of district and local government functionaries, farm men and women and NGOs—'intervention partners' who collaborate in implementing the interventions.

The ongoing activities (e.g. assessment of FSN intervention at the end of each crop cycle with the farm and non-farm community) and overall progress of the project with respect to set milestones and deliverables will be regularly monitored by the project team as per the protocol developed to achieve the expected outcomes. In this connection, participatory assessment monitoring and evaluation will be facilitated during demonstration and FFS, in which men and women farmers are involved in fine tuning the context-specific FSN system. The baseline survey in the study locations forms the base for decisions on design of the intervention by the project team in consultation with the community and technology and stakeholder platforms.

Initiated in mid-2013, steps 1–5 listed in Table 3 have been undertaken in the FSN villages. The on-farm crop demonstrations have included orange fleshed sweet potato, biofortified pearl millet, nutrition garden and use of fertilizer deep placement technology. Survey nos. 2–11 listed in Table 1 will be completed in the FSN and non-FSN villages by August 2014, and household level farm and non-farm interventions are set to commence in the FSN villages.

Rationale and Approvals

All the households in the study region involving both FSN and non-FSN villages are being administered the demographic, socio-economic, occupation, employment, income and expenditure (focusing on agricultural activities),

anthropometric and morbidity survey schedules, to support the analysis of the proposed study. Intra-household diet survey based on 24-h recall and gender survey schedules are also being administered on a subsample of households, including all households with children in the 1–5 years age group across each land category, viz. landless, small and marginal, and medium, with a minimum of 50 households in each category so as to strengthen the interpretation and facilitate subgroup analysis. Where the number of households with children in the 1–5 years age group was found to be <50 in any category, households with adolescent girls in the 12–17 years age group were randomly selected to get the desired number.

For collecting blood samples for biochemical analysis, given that the numbers for drawing samples is less than required, the entire population of children 1–5 years, adolescent girls 12–17 years and women 18–45 years in the FSN and non-FSN villages is being covered. Blood samples of children 1–5 years will be tested for both serum vitamin A and haemoglobin levels and of adolescent girls and women for only haemoglobin.

Approval has been obtained from the Ethics Committee of the MSSRF Board of Trustees for drawing blood samples from members in FSN and non-FSN villages. The concerned district authorities have been informed, the purpose explained at village meetings, and prior consent taken from each individual before drawing the sample. The blood samples are being drawn by DMLT-qualified technicians recruited for the purpose and are being sent to the National Institute of Nutrition, Hyderabad, for analysis.

Conclusions

The FSN model will, in essence, demonstrate the feasibility of a wide-ranging and sustainable nutrition-sensitive agricultural intervention. The study protocol described will capture the extent of productivity and profitability enhancement in the farming system contributing to enhanced spending by the household towards balanced diet and more intake of nutritionally rich food, and extent to which a pro-nutrition farming system design can be adopted by households with different levels of asset base. The evidence of effective models of connecting agriculture with the nutritional outcomes generated through this study could be used to frame gender- and nutrition-sensitive farming systems in different agro-ecological zones of the country and the region. The study will also help to assess the role biofortification of crops can play in the alleviation of micronutrient malnutrition.

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