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Enhancing nutritional security and promoting women empowerment in India through value chain interventions on minor millets

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ABSTRACT: India faces a significant nutrition challenge. Previous interventions to improve food and nutrition security have not been successful and women's important contributions to agriculture and biodiversity conservation have been ignored. This paper shares lessons learnt in the framework of a project undertaken by Bioversity International, supported by the International Fund for Agricultural Development on neglected and underutilized species (NUS),which intended to mainstream nutritious minor millets, which appear to be able to make a significant contribution of interlinked livelihood goals in India. The paper concludes with recommendations for research, sustainable agriculture, government actions, value chain interventions and mainstreaming of NUS.

*Key words: :*minor millets, nutrition, food security, women's empowerment, food policy, India

Mainstreaming minor millets in India

Ideally, agricultural and poverty-reduction strategies should be aimed at improving access to adequate dietary variety for vulnerable population groups. However, historically various governmental food security plans in India appeared not to have taken this principle into consideration and in some cases, even led to a worsening of dietary diversity; by marginalizing nutritious-rich traditional crops and bypassing the participatory role of women in agriculture, nutrition security and biodiversity conservation. . Based on past research findings, Bioversity International and the M.S. Swaminathan Research Foundation (MSSRF) have been testing out novel approaches to enhance the food and nutrition security of rural people, focusing specifically on minor millets. Minor millets are a very good example of how neglected and underutilized species (NUS), can effectively contribute to a variety of closely inter-linked livelihood goals, such as food and nutrition security, health, women's empowerment and increased income for the rural poor. The article starts by reviewing India's current nutrition challenge and analyzes the strategic role played by minor millets in nutrition security and concludes with policy recommendations needed to mainstream agro-biodiversity-based practices into government actions.

India's nutrition challenge

India is facing a significant nutrition challenge. UNICEF statistics show that the burden of wasting (abnormal low weight for height and indicator of acute malnutrition) is highest in India, which has more than 25 million wasted children. This exceeds the combined burden of the next nine high-burden countries. Similarly, India is home to greatest absolute burden of stunted children (abnormal low height for age). This condition, an indicator of chronic malnutrition, in such a highly populated country, accounts for 38% share of the world's stunting burden. As per the latest estimations in Sub-Saharan Africa 21 % of children

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under five are underweight (abnormal low weight for age), whereas in India and South Asia this prevalence is 43 % and 33 % respectively [1]. Furthermore, 28% of the infants are born with a low birth weight (≤2,500 grams at birth), and have a greater chance of suffering from child morbidity or mortality. Of the ones who survive infancy, many will be suffering from cognitive and neurological impairment and will be stunted as adults[2]. Malnutrition is also reflected in the statistics for adults. According to the National Family Health Survey held in 2005-2006(NFHS-3, 2007), 71.1% of Indian women and 67.4 % of men aged 15-49 have a body mass index (BMI) lower than 18.5.

Iron deficiency anemia in India

Undernourishment is an important cause of micronutrient deficiencies, including iron deficiency. Iron deficiency anemia is one of the most prevalent micronutrient deficiencies worldwide. Iron deficiency in infants and young children, can lead to impaired psychomotor development, coordination and scholastic achievement, and reduced physical activity levels. Amongst pregnant women, iron deficiency anemia is associated with an increased risk of maternal mortality, maternal morbidity and obstetrical complications. The unborn child risks intrauterine growth retardation, low birth weight and fetal morbidity and mortality[3]. Anemia remains one of the most important indirect causes of maternal mortality in India [4].

The NFHS-3 conducted in 2005-2006 shows that 55% of Indian women, 24% of Indian men and 59% of pregnant women are anemic. For children these figures are even worse: 70% of the children aged 6-59 months are anemic, 26% are mildly anemic (hemoglobin level of 10.0-10.9 g/dl), 40%moderately anemic (7.0-9.9 g/dl), and 3%severely anemic (less than 7.0 g/dl). In fact, the condition is so common that in all but 4 states (Goa, Manipur, Mizoram, and Kerala) more than half of children are anemic. Since 1998-1999 the prevalence of anemia has only increased [4]. Due to the high prevalence of anemia in the country, iron deficiency in India deserves a high priority. The main reasons identified as the cause for this prevalence are low dietary intake and poor bioavailability. These factors should be included in interventions, which aim to reduce anemia.

Child malnutrition is responsible for 22% of the country's burden of disease in India[1] and is undoubtedly India's biggest public health problem[5]. Despite India's efforts to improve nutritional status programs such as the integrated Child Development Services Programme and the Public Distribution System (PDS) (Ramalingaswami, Jonsson, and Rohde 1996; Kataki 2002 [6], there has only been a marginal reduction in the percentage of young children who are stunted and underweight. In fact the percentage of young children who are wasted has slightly increased[7]. With an average annual rate of underweight reduction of only 0.9% between 1990 and 2008, India has made insufficient progress towards reaching the millennium development goal no.1.c: to halve, between 1990 and 2015, the proportion of people who suffer from hunger (UNICEF 2008[1]. Thus, it can be concluded that greater efforts need to be made in India to reach nutrition security: Adequate nutritional status in terms of protein, energy, vitamins, and minerals for all household members at all times [8].

Green revolution and nutrition

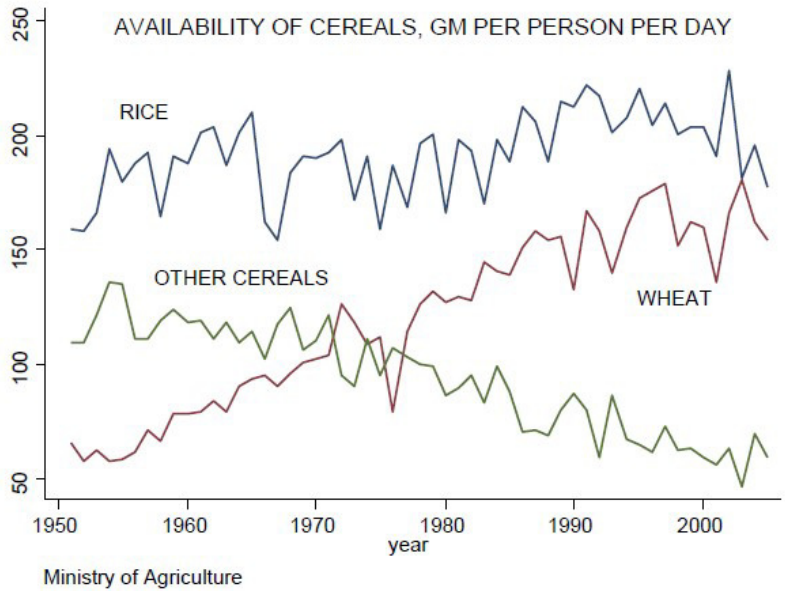
During the green revolution, improved crop varieties, irrigation and a dramatic increase in petroleum based inputs such as pesticides and fertilizers resulted in an enormous increase in yield in Asia in the late 1960s[9]. Researchers at the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT), together with national research programs developed modern short-duration high-yielding varieties (HYVs) of wheat and rice which could grow at any time of the year and responded much better to fertilizers [10]. Since

the yield and profitability of those new crops was higher, more and more farmers started to cultivate wheat and rice at the expense of traditional crops. As a result, cereal production in Asia doubled between 1970 and 1995[11]. In India during the 1970s and 1980s, farmers used land to cultivate wheat and rice; therefore, eliminated pulses and coarse cereals, such as millets, from the fields. This resulted in a sharp increase in the price of pulses, and thus a drop in the per capita consumption[12]. Pulses are an essential source of protein in Indian diet and displacement of pulses from diet decreased the supply of utilizable essential amino acids due[13]. Table 1. shows the supplies of basic foodstuffs in India from 1960 to1995. It is argued however that despite the increase in per capita protein from plants shown here. The availability of coarse cereals has declined by more than half the initial amount, over the last fifty years (Figure 1). Despite some

Table 1
Per capita supplies of basic foodstuffs in India 1960-1995 (kg/person/year)

Commodity	1960	1970	1980	1990	1995
Rice	72.1	68.1	67.5	78.0	76.5
Wheat	27.8	35.7	45.7	53.7	58.3
Coarse cereals	44.0	42.9	36.3	31.3	28.8
Pulses	23.0	16.6	12.5	13.7	13.3
Total Food grains	66.9	163.3	162.0	176.7	176.9
Vegetables	37.0	42.5	47.7	52.2	74.0
Fruits	26.5	26.2	26.5	28.7	34.8
Starchy roots	10.4	17.0	19.7	19.8	21.3
Sugars	19.2	19.2	19.9	22.7	23.1
Vegetable oils	4.1	4.1	5.3	6.5	7.1
Milk[a]	38.6	33.6	39.2	54.7	60.2
Meat[b]	5.9	6.9	7.5	9.4	9.9
NOTE: All quantities based on three-year averages					
[a] Cow, buffalo and goat milk [b] Beef, mutton, pork, poultry, egg and seafood					
SOURCE: Data from Hopper (1999)[13]					

Figure 1
Availability of rice, wheat and other cereals (g/person/day)



NOTE: 'Other cereals' are mainly the "coarse" cereal group consisting of maize, barley, jowar (sorghum), ragi (finger millet) and bajra (pearl millet) SOURCE: Deaton and Drèze (2009)[14].

temporary increases, the declining trend of availability has long been established [14]. Although wheat production between 1983 and 2005 increased ten-fold and rice production four-fold, Deaton and Drèze (2009) report a decline in energy intake per capita in India; from 2,240 to 2,047 kcal for rural populations and from 2,070 to 2,021 kcal for urban populations. These values are below the Recommended Dietary Allowances (RDA) given by Indian Council of Medical Research (2009), 2730 kcal/day for a man and 2230 kcal/day for a woman doing moderate work.

The Asian Green Revolution brought a rice-wheat rotation which resulted in the displacement of grain and fodder legumes helpful in ameliorating soil fertility[15], along with a narrowing of the food base. Research and extension programs have focused mostly on few crops, namely maize, wheat and rice which supplies the bulk of the protein and energy needs for India. The large dependence on a narrow range of cereal crops and varieties determined the loss of biodiversity on farms[11][16] and contributed to a severe reduction of dietary diversity[13]. Crop and dietary diversification strategies improve long-term sustainability of the food resources in communities, particularly when traditional knowledge and socio-cultural values of the community are being considered [17][18]. Higher dietary diversity positively influences nutritional status of the population and lower the incidence of all forms of malnutrition[12].

The Green Revolution apparently improved food security since it raised income for some of the farmers, increased per capita availability of cereals through an increase in production and was able to reduce food prices. Critics however noted how this was not the case in many marginal areas where HYV performed insufficiently due to poor soil conditions or because of the lack of agricultural inputs, which were often unavailable to the majority of poor small holder farmers. Some detractors also point out that HYVs were dependent on huge amounts of fertilizers, which have toxic properties when they are administered without sufficient water. Availability of water for irrigation is also often cited as an additional drawback in the adoption of HYVs. The densely planted, nitrogen rich, irrigated plants appeared to be very vulnerable to herbivores, pests and plant diseases and, as a solution to this problem, new synthetic pesticides were developed, creating a further dependence on biotech agricultural corporations[19].

Getting back to local food systems

The Asian green revolution clearly demonstrated that by only introducing HYV and increasing food production, India's malnutrition problem cannot be solved sustainably. Such a condition is now even further aggravated by climate change. There is a growing understanding that in order to contribute effectively to reducing malnutrition in India, a change of paradigm is needed whereby dietary diversification, the nutritional value of traditional crops and their beneficial effect on the agro ecosystem are fully recognized, valorized and promoted.

Many of the secondary food grains such as pulses, which are important sources of protein in traditional Indian vegetarian diets, as well as millets such as sorghum, pearl millet and finger millet, which serve as staples in dry land areas, are rich in micronutrients. Unfortunately, they have been underemphasized by research and development and policy. Another factor contributing to a decrease in cultivation and intake of these food grains of the traditional Indian diet, is their marginalization by society. Millets, for example, are erroneously considered poor man's food and a sign of cultural and technical backwardness[20].

The Policy gap

Secondary food grains have been neglected by research and policy. The 10th Five Year Plan, developed by the Indian planning commission in 2002[4], shows how millets have not been receiving

the required policy support, until a decade ago the consumption of coarse cereal declined, for example in Uttar Pradesh, it declined from 5.0 kg per capita per month in 1972-1973 to 0.8 kg per capita per month in 1993-1994, while the consumption of. rice and wheat increased: for rice from 2.6 kg per capita per month to 3.5 kg and that of wheat from 6.1 kg to 8.1 kg per month. The Indian government argued that as *'rice and wheat are the basic necessities for the poor*', cannot be expelled from purview of Targeted Public Distribution System (TPDS), therefore indicating that food subsidies should be restricted to these two commodities. Despite the fact that coarse cereals cause lower environmental damage during production, they were advocated not to be included in PDS, as there was no standard variety and also due to their shorter shelf life, Furthermore, in point 3.4.24. e/f it is explicitly mentioned that all further attempts to include additional commodities under the coverage of food subsidy should be resisted. In addition, the government only provided a one-time supply of 100 kg of wheat or rice to each grain bank managed by the community-based support systems (Planning Commission, 2002, GOI).These strategies made only rice and wheat affordable to the poor, making other crops like minor cereals and pulses too costly. This reduced the dietary diversity of Indian diet and led to widespread of micronutrient deficiencies. In the 11th Five-Year Plan (2007-2012), the government of India acknowledges the need for diversification of diets to combat nutrient deficiencies, stating that the availability, consumption of, and access to different types of micronutrient-rich foods should be improved. With nutrition security being one of the considerations of the TPDS, it includes other commodity crops such as pulses. The National Development Council (NDC) therefore adopted a resolution to initiate a National Food Security Mission in 2007 with goal to increase production of rice (by 10 MT), wheat (by 8 MT) and pulses (by 2 MT) by 2011/12, however, nutritious–rich minor millets were left out. The latest Five-Year Plan (2012-2017) (Planning Commission Government of India 2013) makes further steps in acknowledging the importance of millets:(1) calling on crops that "*can withstand climate stress*" (cfr page 229 of Vol. 1); (2) calling for additional 2 million tons of production of millet[1] through the NSFM (National Security Food Mission launched through the previous Five-Year Plan) (cfr page 42 of Vol. 2); and (3) advocating actions to *"ensure food and nutrition security at household level by making the essential food grains (rice, wheat and coarse grains), edible oils and sugar available through the Targeted Public Distribution System"* (cfr page 217 of Vol. 3). However, more supportive policies was approved by the Parliament of India only last 12 September 2013[2] under National Food Security Bill, (known also as the Right to Food Bill) where the Indian Government is committed to provide subsidized food grains to app. 2/3 of India's 1.2 billion people. For the first time, the Government refers to coarse cereals (category that includes minor millets) in addition to rice and wheat, which was received by many observers as a great achievement in the direction of strengthening nutrition security in the country. Detractors argue that the Bill fails however to find proper remedies to the root causes of malnutrition in the country such as access to water, sanitation facilities and public health education and other issues like poor infrastructures in food delivery systems, scarce attention to sustainable farming methods, and poor land use. With regard to the implications that the Bill will have on the production of minor millets, it is worth reflecting that a well thought out mechanism for the production of minor millets is now needed by the country. Considering the different degrees of production levels of minor millets across India, many observers advocate that the States, rather than the central Government, should implement production of these crops in harmony with local crop cultivation patterns and demands.

One of the key individuals behind the inclusion of minor millets in the Food Security Bill is Prof. M.S. Swaminathan who has been advocating in many fora the need for developing an enabling environment for the promotion of minor millets. During the 36th Session of the Committee on World Food Security on October 11, 2010, Prof. Swaminathan, as the Chairperson of the Steering Committee of the High Level Panel of Experts on Food Security and Nutrition stated that,"*The solution for the food and nutrition security problem requires interventions generating a synergy among technology, public policy and famers' efforts*". One of the difficulties in forming such a synergy is that there is a need to pursue actions on solid ground in order to ensure sustainable effects. He therefore advocates political decisions that promote community level food security systems based on climate resilient farm technologies and further stressed that priority should be given to the inclusion of nutrition-rich in the food basket[21]. In the light of the recently approved Indian Law, we can now say that Swaminathan's advocacy has been highly successful and Bill can set the example for similar policy interventions in other countries.

Empowering women as the custodians of nutrition security and biodiversity conservation

To maximize the effect of agricultural interventions for nutrition outcomes the most effective results are obtained when technology interventions are complemented by investments in nutrition education and health services, and targeted in such a way that women are empowered with additional spending power[22]. During the Asian Green Revolution, poor attention was paid to female-dominated traditional agriculture and knowledge and as advanced, often bypassed regardless of the fact that women contribute substantially to macro-level food security. Women, in fact, were displaced from their traditional roles in agriculture, partly as a result of mechanization[23]. After all, according to the United Nations Development Programme (UNDP)Human Development Report of 2004, 74% of women are economically active in agriculture, having an essential role in the value chain of crops, thereby contributing to nutrition security at the household level[24].

Due to different experiences and activities, women and men have different but complementary knowledge on plant species. This gender differentiated knowledge is of great importance for the sustainable conservation and use of agro biodiversity. Women in fact select the varieties which, in their opinion, are most useful on a household and community level[25]. Women have been found to reflect in a more comprehensive way on detailed criteria like taste, color, size, texture, cooking time, crop yield, ease of processing and access, grain formation and resistance to pests and insects when selecting varieties. These selection skills, which have been developed over years of experience aim at diminishing households' risks [26][27]. Male farmers on the other hand, select varieties according to male's main responsibility, mostly income generation and therefore high yield and good market price receive higher priority [28]. In smallholder agriculture, women farmers are often in charge of the selection, improvement and adaptation of plant varieties [25]. A study performed in India showed that empowering women by giving them increased decision-making authority in participatory variety selection (PVS) of rice, improved the development of varieties best suited to the environment [29],which under changing environments is important to ensure food security. The same study showed an increase in confidence amongst women in their decisions and opinions. In most countries, women focus mostly on subsistence production of food crops, on farms or in home gardens, whereas men take care of commercial farming. But for women farmers to contribute more effectively to food and nutrition

security, they need access to land, management control of land-based resources and the economic incentives[30].During the green revolution women lost influence and control over production and access to resources, men frequently could take advantage of extension services and had the ability to purchase seeds, fertilizers and the necessary technologies. Women and men use different networks, including formal and informal community based networks, for exchanging seeds [28]. After harvesting, the processing and storage of food crops is also mainly a job of the women [26]. Women from poor households practise a variety of income-generating and expenditure-saving activities that can supplementing male contributions or can represent the primary or sole source of household livelihoods..

A study on demographic and health surveys data related to 117,242 children, under three years of age in 36 developing countries, demonstrated that the status of women is an important determinant of child nutritional status. Women with low status tend to have weaker control over household resources, tighter time constraints, less access to information and health services and lower self-esteem. These factors are directly associated with women's nutritional status and the quality of care they received, and in turn to children's birth weights and the quality of care they receive[31].Furthermore, many studies have revealed that income or properties controlled by women are more likely to be spent on or used for items that benefit children, such as food, clothing and health care, [32] [33], while men are more likely to spend a considerable part of theirs on personal goods such as alcohol, tobacco, etc.[34]. Research in several developing countries of Asia, Africa and Latin America demonstrated that advancements in household food security and nutrition are related to women's access to income and their role in household decisions on expenditure [30]. Women also play a key role in determining which food and other products to maintain at home for consumption and which to sell at the local market[26]. A study conducted in Andhra Pradesh, India, showed that interventions are needed in two dimensions of female autonomy (financial and physical) which,both/independentlyaffect child growth[35].

IFAD-NUS Projects: The First UN Project on neglected and underutilized species

If we are to address food security effectively, a change in paradigm is needed. Frison (2006) states "*In view of current knowledge of synergies in the physiologic functions of nutrients, the focus of interventions needs to be on improving overall diet quality while at the same time improving the wellbeing of rural and urban population*" (Frison et al. 2006)[17]. Recognizing other important determinants of nutritional security, such as healthcare, childcare and food access [36], the authors believe that, for the purpose of addressing the nutrition challenge, minor millets (and other NUS) can make a huge difference in India. Minor millets, having a unique strength to counter hidden hunger as it has so much micronutrients[37], are essential in fulfilling the macro and micronutrient requirements and crucial in reversing the poverty-micronutrient malnutrition trap in developing countries[17] and thereby contribute to wholesome nutrition security. This is the rationale that has guided the interventions of the IFAD-NUS project carried out between 2002 and 2010, which we shall describe in the following sections.

The outcomes of the IFAD-NUS project will be used to answer the key question behind the main objective of this paper, that is 'how can the promotion of minor millets contribute to nutrition security and women empowerment in India' Our discourse will be supported also by findings emerged through an external evaluation carried out on the IFAD-NUS project[38] and subsequent impact assessment studies made by Bioversity [39], [40].

In 2002, the IFAD funded project "Enhancing the contribution of neglected and underutilized species

to food security and to incomes of the rural poor, Asia Component-Nutritious Millets" was launched in 7 countries across Latin America, North Africa, West and South Asia (where India was among the participating countries). The project was coordinated at the international level by Bioversity International and by the M.S. Swaminathan Research Foundation for the South Asia component. Later, in 2007, as a follow up initiative, IFAD approved a three year program, "Empowering the rural poor by strengthening their identity, income opportunities and nutritional security through the improved use and marketing of neglected and underutilized species"[39]. The project adopted a community-based, multi-stakeholder and inter-disciplinary framework. It was implemented as a whole in 31 villages spread across four Indian states (Tamil Nadu, Orissa, Karnataka and Uttarakhand) all of which have different agro-ecological, economic, ethnic and cultural conditions: marginal agricultural lands with scarce rainfall in the Deccan plateau, hilly rain fed regions in the Eastern Ghats and highly fragile subtropical to temperate Himalayan Mountains. The project was estimated to influence around 753 households. Recognizing their nutritious qualities and importance in climate change adaptation, the IFAD-NUS project in India included finger millet (*Eleusine coracana* L.), foxtail millet (*Setaria italica* L.), little millet (*Panicum sumatrense*) and barnyard millet (*Echinochloa crusgalli* and *E. colona* (L.). Interventions were undertaken to make them a viable income source and a nutritious food option. Genetic material and information on its conservation and use was provided to farmers by establishing village gene-seed-grain banks; better varieties were developed by Participatory Varietal Selection; cultivation practices were improved; more efficient processing technologies were developed; nutritional and industrial values of crops and products were characterized; sustainable enterprises were initiated; community members were trained and public awareness was raised.

The role of minor millets in nutrition security

Minor millets were selected by the project due to their hardiness, resilience to varied agro-climatic dangers and importance in marginal agriculture, as well as the fact that they also played an essential role in food and nutrition security of the people living in the project's area. When assessing the role of NUS in food and nutrition security, it should be stressed that other characteristics than just the caloric content of the plant should be taken into consideration. Minor millets play in fact an important role in the food and nutritional security of the poor, due to their excellent content in macronutrients, minerals, vitamins and fibers. Based on that, they should be rather called 'nutritious millets'. Minor millets contain all essential amino acids needed for an adequate diet[41]. From Table 1.5.1 we can appreciate that compared to rice -the main staple food in India- they are higher in protein. The common feature of minor millets is that lysine is the most limiting amino acid and therefore millets diets should be complemented with legumes to fulfill protein needs[42]. On the other end, the sulphur-containing amino acid content in finger millet is equal to that of milk protein[43]. Interestingly, the fermentation of finger millet increases the percentages of free amino acids, as protein binding phytates are degraded during the fermentation process, thereby improving the bioavailability[43].

Literature shows that the fat from finger millets contains the essential fatty acid linoleic acid[44] Fat content of finger millet (1.5-2.0%), although low, is high in polyunsaturated fatty acids (PUFA)[43]. PUFAs are preferred over saturated fatty acid because they reduce the risk of cardiovascular disease.

Kamath and Belavady (1980) found that small millets are superior to rice and wheat as a source of dietary fiber. The total dietary fiber in finger

millet (18.6%) was higher than that in sorghum (14.2%), wheat (17.2%) and rice (8.3%)[45]. Worth noting that adequate fiber intakes has potential health benefits such as normalization of bowel movements and helping maintain bowel health, lowering of cholesterol levels, helping control blood sugar levels and aiding in achieving healthy weight [46].

For these reasons, minor millets could be excellent ingredients for the preparation of fiber-rich healthier bread products[47] Diabetes constitutes a severe health problem in India, which has the highest incidence of this disease worldwide. WHO reported in 2000 that 31.7 million of people suffering from this ailment and by 2030 incidence is predicted to rise to 79.4 million (WHO 2013). Diets containing kodo (*Paspalum scrobiculatum*) and finger millet flour have been found to have potential benefits to mitigate or delay the onset of diabetes related complications, since they can reduce blood glucose, lower blood cholesterol and protect against alloxan-induced oxidative stress in diabetic rats and these positive effects are attributable to the fiber and antioxidant phenolics found in these crops[44].

Starchy foods which are digested gradually and are followed by a lower blood glucose response are more beneficial to health and for the management of diabetes and hyperlipidemia[48]. They have a low glycemic index (measure of the effect of carbohydrates on blood sugar levels). Some of the products produced by using minor millets have a low glycemic index, meaning 55 or lower[49]. For example Laddu, an Indian sweet which is an integral part of most Hindu festivals and celebrations, prepared with foxtail millet, has a glycemic index of only 24, whereas other products prepared with minor millets have a higher glycemic index. These are for example, ragi made of finger millet, which has a glycemic index of 68, classifying the product in the category of medium glycemic index (56-59)[50]. As a reference, products such as white bread, cornflakes and donuts have a high glycemic index (>70).

Consumption of finger millet based diets has been reported to result in significantly lower plasma glucose levels than consumption if diets based on rice or wheat due to the higher fiber content of finger millet[51]. On the other hand, an earlier study concluded that finger millet is not very effective in lowering blood glucose levels[52]. Further studies seem to be warranted to confirm that since it is also argued that recipes used to process finger millet in this work might have had an influence on its outcome.

From Table 2 the great advantage of millets becomes even more apparent when iron (Fe) and calcium (Ca) content are to be considered.

Table 2
Nutrient composition of minor millets and other cereals (per 100g edible portion)

Food	Protein	Fat (g) (g)	Carbo-Hydrate(g)	Ca (mg)	Fe (mg)	Vitamin B1 (mg)	Vitamin B2 (mg)	Vitamin B1 (mg)
Rice (brown)	7.9	2.7	76	33	1.8	0.41	0.04	4.3
Wheat	11.6	2	71	30	3.5	0.41	0.1	5.1
Maize	9.2	4.6	73	26	2.7	0.38	0.2	3.6
Sorghum	10.4	3.1	70.7	25	5.4	0.38	0.15	4.3
Pearl millet	11.8	4.8	67	42	11	0.38	0.21	2.8
Finger millet	7.7	1.5	72.6	350	3.9	0.42	0.19	1.1
Foxtail millet	11.2	4	63.2	31	2.8	0.59	0.11	3.2
Proso millet	12.5	3.5	63.8	8	2.9	0.41	0.28	4.5
Little millet	9.7	5.2	60.9	17	9.3	0.3	0.09	3.2
Barnyard millet	11	3.9	55	22	18.6	0.33	0.1	4.2
Kodo millet	9.8	3.6	66.6	35	1.7	0.15	0.09	2
SOURCE: Data from Hulse, Laing, and Pearson (1980)								

Compared to rice and wheat, finger millet is in fact extremely high in calcium, the highest content among all cereals (334 mg per edible portion)[53]. Of these 334 mg, only 162 mg/100 g is bioavailable in the raw grain, however processing by fermentation and germination improves its bioavailability to 227 mg/100 g[54].

The same is true for the products made with little millet and foxtail millet: In table 3 it is shown that calcium content of 100 g of *paddu* prepared with little millets (94 mg) is much higher than when

Table 3
Nutritive value of ethnic food made of rice and little millets: Paddu (per 100g)

Nutrient	Rice	Little millet
Calories(kcal)	667	643
Protein(g)	19	21
Fat(g)	11	13
Carbohydrates(g)	123	112
Crude fibre(g)	1	12
Calcium(mg)	69	94
SOURCE: Gopalan (1989)[53].		

these food items are prepared with rice flour (69 mg). Dietary calcium intake of both the urban and the rural populations in Southern India is low compared with the recommended dietary allowance of 600 mg/d. Poor calcium status can lead to a defect in mineralization of bone, rickets in children and osteomalacia in adults[55]. Finger millet could be used to overcome the calcium deficiency of a rice diet. The investigations made in the IFAD-NUS project to assess the nutrition/ health outcomes have also showed that in Karnataka State women's adequate dietary level of calcium was directly linked to their consumption of finger millet[56]. Iron deficiency occurs when diets are based mostly on staple foods and include little meat (WHO 2002). This can be seen in India where meat consumption is very low and depends heavily on income class [13]. Regarding the strong limitations iron deficiency anemia sets on human and national development, attention should be paid to the iron content of crops used as staple food. Mainstreaming minor millets as a nutritious food can bring substantial benefits in addressing iron deficiency anemia in India. Table 2 shows that compared to rice and wheat, especially barnyard and little millets contain much more iron. Iron from plant source is less easily absorbed than iron from meat source, but processing the finger millet will improve its iron availability [54].

During the IFAD-NUS project, the nutritional status of children, fed for three months with ragi (finger millet) or foxtail millet was assessed. Children fed with millet showed an improvement with respect to weight and hemoglobin level compared to the control group fed with rice. Hemoglobin level was significantly increased in the groups fed with millets to the extent of 32-37.6%[56].Including ascorbic acid rich fruits in the dinner can enhance uptake of minor millets' non-heme iron[57].

The prevalence of zinc deficiency, contributing to growth retardation, diarrhea, immune deficiency, skin and eye lesions, delayed sexual maturation and behavioral changes (WHO 2000), is very high in South Asia where it varies between 34% and 73% [58]. National risk of zinc deficiency in children under 5 years in India is very high[59]. One quarter of the total Indian population is at risk of inadequate zinc intake, and therefore it is recognized as a public health problem [59]. Including minor millets in their diets might contribute to fulfilling the zinc needs of the Indian people. Finger millets contain more zinc than rice but its bio accessibility is lower[60]. Finger millets are rich sources of phytates, which form complexes with zinc, iron and calcium and reduce their bioavailability. However, processing finger millet can reduce the presence of those complexes considerably and enhance the zinc bioavailability[54]. Data indicates that food processing procedures such as heat treatment (cooking), fermentation, germination, malting and soaking, as well as treatment with phytase, can improve zinc bioavailability in foods by decreasing the amount of dietary phytate or its lesser phosphorylated derivatives[23]

When it comes to vitamins, Table 2 shows that foxtail millet in particular is rich in vitamin B1 (0.59 mg per 100 g). The riboflavin (vitamin B2) content of millets is generally higher than rice, whereas rice and wheat are generally higher in niacin (vitamin B3).

Food products development

The non-availability of processed products similar to rice or wheat is one of the primary reasons for minor millets' consumption being confined to traditional consumers. In the IFAD-NUS project, novel millet products were developed. The fermentation and germination processes involved in the preparation of some of these products promote starch and protein hydrolysis, and reduced pH and phytates, therefore increasing mineral bioavailability, free sugars and amino acids of products made from finger millet[54]. In addition to nutritional quality, other characteristics of the minor millets made them appropriate for food product development. For example, the crispy texture of foxtail millet makes it very suitable for biscuits and fried products. The soft, non-sticky starch consistency of finger millet is very suitable for making 'halwa' and the light, puffy characteristics of little millet are ideal for making fermented ethnic products like 'idli' and 'dosa'. Natural storage stability of some of these products at room temperature was found to be adequate for about two months[37]. Through the above methods of preparation, value was added to products avoiding nutritional degradation and the range of palatable dishes was extended. Malleshi[47] states that some of the sweet dishes prepared from foxtail millet have superior taste and texture compared to rice. Minor millets can also be used for the preparation of tasty, crispy flakes and noodles with attractive color and good cooking qualities.

The development of the value-added products was targeting particularly women participating in Self-Help Groups, who have been trained on processing, value addition, marketing, packaging, quality standards, account keeping and entrepreneurship. This capacity building intervention has empowered women in generating more incomes and this dimension is particularly worth highlighting given the conditions of social marginalization experienced by many women in the rural regions of India.

Empowering women as actors of minor millets value chains

Following is a list of recommendations on how to best pursue the use enhancement of minor millets in India to the benefits of the more vulnerable people, including women. These reflections, some of which of practical nature, have emerged from the IFAD NUS and other relevant projects implemented in so far in India and are referring to key domains of the value chain of minor millets, viz. cultivation, processing, value addition, packaging, distribution, storage, marketing and consumption.

Cultivation

First of all, promoting small millets demands the farmers be made aware of the financial and environmental benefits of their cultivation. Farmers can also be encouraged to grow millets by enrolling in carbon credit programs that will compensate losses incurred due to longer crop cycles in case they choose to use traditional crops. As seen in the case of Kolli Hills -by linking producers - CBOs (like the "Kolli Hills Agrobiodiversity Conserver's Federation" KHABCOFED, Kolli Hills Agri-bioresource Farmers Producer Company - KAHBPCOL) can capitalize on the growing consumer demand for organic food. At the same time, they could also consider supplying Government's programmes such as the '*Midday Meal Scheme of School Feeding Programme*', by substituting other grains with small millets through the public distribution system (PDS) now covering also minor millets. Another important intervention consists in partnering in the diversification of the millet based

foods of the '*Integrated Child Development Services*" (ICDS)in view of the millet prospects resulting from the implementation of the Food Security Act 2013 in each Indian State.

Processing

Processing agricultural produce requires linkages with technical support institutions such as agricultural universities, competitors or other producers and consumers. Some important avenues to explore for supporting use enhancement goals to the benefits of value chain actors esp. women, may include the development of new technologies to minimize waste in de-husking as well as new processes to make use of existing processing waste for possible value-added products; along with continued experimentation with traditional and new recipes through sensorial tests with customers to help improve acceptability of value-added products across different streams of population.

Value addition

Adding value to products requires a clear understanding of the value chain. Such an understanding helps producers cater to different players at higher ends of the value chain. To ensure a successful value chain, quality control mechanism are needed; more research on methods to reduce product contamination is also required along with actions meant to build up consumers' trust by clearly enumerating product ingredients, lack of preservatives and use of healthy processing methods. Upgrading the capacities of women Self Help Groups and other actors of the value chain is essential and need to be supported. Teaching consumers how to use minor millets by including simple recipe books in the product packages and playing demonstration videos at the point of sale is also another area worth investing efforts on.

Packaging

Packaging is an important aspect of branding. It builds brand identity, and allows consumers to easily identify products thus building customer loyalty. Ways to do this include: exploring innovative packaging options such as vacuum packing which increases shelf life without using chemicals; provide cooking instructions using simple visuals or including a recipe pamphlet, creating and using attractive corporate identity elements such as a logo and/or a tag-line.

Distribution

An efficient distribution network facilitates the timely and uninterrupted supply of products to retailers and consumers. As supply chains expand, so must the scope and reach out to distribution networks. This activity requires increasing the number of distributors and acquiring a credit line, which will allow producer associations to expand their retailers' base.

Storage

Storage is an important component of any production process that has reached a critical scale. Farmers require a central storage facility in order to increase millet production and to reap higher margins from seasonal price fluctuations. Producers can access local government programmes for help with storage infrastructure.

Marketing

Minor millets producers, would benefit from a combination of short-term and long-term marketing strategies. Short-term strategies would include: researching different customer segments so that they can market their products in a more targeted manner; developing promotional material like banners and flyers to raise brand visibility; running health awareness campaigns in metros to promote the nutritional benefits of small millets; holding cooking demonstrations at food courts and corporate canteens to reach an urban audience; establishing linkages to hotel chains, eateries, schools or educational institutions with eco-friendly philosophies; Mid- to long-term strategies would involve: establishing an online shopping portal to sell natural or organic products; dispelling

myths about millets to better promote the brand; disseminating information about the benefits and appeal of millet-based products in schools

Consumption

Millets-based cooking demonstrations, *Food Mela*, Food Diversity Fairs in production points and User Points are among the most useful practices that can be supported by the National Nutrition Mission of the States in India in which women -as ambassadors of the nutritional and healthy benefits of millets- would play a key role. Their role would be also particularly significant when targeting children, adolescent girls and aged people.

Conclusions

The economic conditions of a vast majority of India's population is so poor that they are in no position to afford even the least expensive balanced diets [5].It is important to remember that most smallholder farmers, including those in the subcontinent, are net food buyers. Increasing disposable income is therefore an essential avenue for better nutrition. The lessons learnt through the IFAD NUS international research effort demonstrate that currently marginalized crops, such as minor millets, can in fact contribute to a more affordable nutrition security of the Indian rural and urban poor while also being a valid instrument of economic development as well as of empowerment of women and the vulnerable and marginalized groups of the society. In order for this to occur, interventions are needed in a number of critical domains which we have listed as follows:

1) More research efforts: work is needed to better link agriculture with nutrition and health through the use of nutrition-rich traditional crops. The case of minor millets presented here is in fact just an emblematic case. India is endowed with hundreds of nutritious crops (pulses, fruits, vegetables etc.), whose R&D is still poorly addressed. Although there is an interesting literature compiling these resources and describing their agro-morphological traits, more is needed to validate nutrition and health claims supported by indigenous knowledge.

2) Resilient systems: minor millets are strategic in strengthening the resilience of local production systems, buffering against climate change but also fluctuations of commodity food prices that may dramatically hit the poor. Governments need to be sensitized to this and be requested to urgently develop supportive policies on resilient crops for resilient production and food systems.

3) Food policies: The approved Food Security Act of India including minor millets in the PDS is an excellent move for more resilient production and food systems. However, many other steps are needed to allow its implementation in each State - like Odisha and Karnataka (such as promoting their use through inclusion in the Public Distribution Systems, education and sensitization of public opinion on the value of biodiversity for nutritious and healthier diets and securing adequate supply of millet flour to meet increasing demands).

4) Consistent value chain interventions: as we move forward to broaden the use of traditional crops such as minor millets, we are confronted with a number of shortcomings that affect their value chain which need consistent interventions through holistic value chain approaches [61]. Examples of bottle necks to be addressed include lack of improved varieties and best cultivation practices, poor harvest and post-harvest technology, disorganized markets, limited participation of private sector, poor microcredit support and horizontal and vertical integration along the value chain[62].

5) Mainstreaming: the financial assistance of international agencies such as Swiss Agency for Development and Cooperation (SDC), International Fund for Agriculture and Development (IFAD), the International Development Research Center (IDRC) Canada or the Canadian International Development

Agency (CIDA), Food and Agricultural Organization (FAO) who had been championing the support for enhancing the sustainable conservation and use of NUS at the global level, is most strategic and much appreciated. But in order to achieve a larger and long lasting impact of these nutritious crops on the lives of people, the role of policy makers in supporting the mainstreaming of best practices developed in so far into Governments' actions is most crucial and emphasized in the Global Manifesto on Forgotten Crops (GFAR 2021).

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