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Article

Minor Millets as a Central Element for Sustainably Enhanced Incomes, Empowerment, and Nutrition in Rural India

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Abstract: Minor millets comprise a group of cereal species that are genetically diverse and adapted to a range of marginal growing conditions where major cereals such as wheat, rice, and maize are relatively unsuccessful. Millets require few inputs and withstand severe biotic and abiotic stresses. They are also more nutritious than major cereals. Despite these advantages, neglect in several arenas has resulted in a steady decline in the cultivation of minor millets in India over the past few decades. As part of a United Nations global project on underutilized species, we undertook action research intended to stem the decline in cultivation and enhance the conservation and use of minor millets in 753 households spread across 34 villages in four states of India. Our aim was to improve incomes, nutritional status, and empowerment, especially for women. Overall, our holistic approach to mainstreaming species such as finger millet, little millet, foxtail millet, and barnyard millet indicates that these neglected and underutilized species can play a strategic role in improving many dimensions of livelihoods.

Keywords: neglected and underutilized species (NUS); nutrition; holistic approach; female empowerment; resilience; participatory variety selection (PVS); value chain

1. Introduction

Millets are an agronomic (as opposed to taxonomic) group of grasses that are widely grown for food and fodder. Most have relatively small seeds (compared to major cereals such as wheat and rice) and thrive in arid areas. The most widely grown is pearl millet (*Pennisetum glaucum*), while a secondary group of millets includes foxtail millet (*Setaria italica*), proso millet (*Panicum miliaceum*), finger millet (*Eleusine coracana*), kodo millet (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), and barnyard millet (*Echinochloa colona*) [1]. This secondary group can be thought of as the minor millets, and forms the subject of this paper.

Millets have traditionally played an important role in farming and food culture in many regions of the world, including Sub-Saharan Africa and South Asia [2], with India being the world's largest producer of these crops. Millets mature quickly, a valuable trait important for rain-fed farming, and require relatively few inputs compared to major cereals. They grow under a range of day lengths and in poor soil, making them an attractive crop for marginal farming environments. In addition to these agronomic advantages, millets can offer other benefits in ecological, nutritional, and socioeconomic areas. Despite these potential benefits, however, in India overall production of millets has increased over the past few decades, from 7.7 Mil tons in 1961 to 10.7 in 2012, but the area dedicated to minor millets has fallen. Finger millet declined from 2.3 million ha in 1951–1955 to 1.35 million ha in 2006–2010. Other minor millets declined even more precipitously, from 5.29 million ha to 0.97 million ha over the same period. Productivity for finger millet, in terms of yield per ha, doubled from 704 to 1471 kg ha^{-1} largely thanks to improved varieties more than making up for the decrease in area. The other minor millets recorded more modest gains in productivity, from 410 to 480 kg ha^{-1}, and total production is now less than a quarter of its 1950 value (2.177 MT in 1951–1955 *vs.* 0.467 MT in 2006–2010) [3].

The decline in minor millets in India can be attributed to many factors; agronomic, economic, and social. The Green Revolution of the 1970s saw government promotion of rice and wheat push minor millets into ever more marginal areas. In those areas, millets have come to be regarded as crops of the poor, which they are, and thus to be avoided, an unfortunate consequence. Policy-makers have contributed to this lack of status by keeping millets largely out of the scope of both official research and development and price support agreements. Continuing neglect then hastens the loss of genetic diversity and traditional knowledge about the production, processing, and use of millets. Production is inefficient as a result of the lack of suitable higher-yielding varieties, poor quality seed, and unimproved cultivation practices. Traditional processing methods condemn the women who prepare millets to considerable daily drudgery. In addition, there is a lack of attractive recipes for adding value, a lack of awareness of the nutritional value of millets, poorly organized integration with markets, and generally unfavorable environmental policy.

However, the use enhancement of millets also represents an interesting opportunity to contribute filling the yield gap in food that the world is suffering from. According to one current estimate, increasing yields to"50% of the potential yield in all low-performing areas could increase annual production by 8.46×10^{14} kcal, which is enough to meet the basic caloric requirements of ~850 million people" [4]. While annual yield increases (as a percentage of current yield) in staples like rice and wheat are below 1% now and falling, we argue that directing greater research attention to nutritious cereals like millets would be a highly strategic choice, because it would be more viable and would offer greater

benefits in terms of lower water requirements, adaptation to climate change, and marginal soils, along with social impact in terms of the greater self-reliance of local populations as well as more resilient and accessible food systems. With regard specifically to millets, the yield gap is largely a reflection of existing cultivation technologies that offer ample room for improvement. Seed is usually farm-saved and of poor quality because farmers lack the ability to select seed and store it well. Poverty and food security also threaten the seed supply by sometimes forcing farmers to eat their saved seed. In addition to poor seed stocks, cultivation is not optimal [5]. In many communities where women are mainly responsible for growing millets, few farmers are aware of improved cultivation technologies such as line sowing and fertilizing.

Upon these considerations it was felt that millets represented an important opportunity for a multi-faceted, holistic effort to reverse the situation, with benefits to farmer status, empowerment, and income (especially for women), to conservation, to nutrition, to the environment, and, ultimately, to food and nutrition security. This represents the scope of the international Research for Development effort carried out from 2001 to 2010, the methodologies and results of which are presented in this paper. With regard to the focus on millets of such a project, it must be mentioned that this had been brought forward by a multi-stakeholder consultation that took place in India in 2001. Out of several NUS still grown in local production systems [6], millets were seen by farmers and other user groups as offering greater comparative advantages compared to other species, in view of their important nutritional profiles, income generation opportunities, and resilience to climate change. The choice of India as one of the target countries for the project was made on the basis of several considerations, including the possible impact in large marginalized agricultural production areas inhabited by poor and vulnerable people, the interest of national research programs, and the valuable crop improvement results of NARS. The work presented here refers to the first two phases of the so called "IFAD NUS Project", whose third phase (2011–2015) is currently still under implementation.

2. Methods

Given the complex interactions among the factors surrounding the decline of minor millets and the changes sought, we adopted a holistic framework to address the many and varied inter-related segments of the value chain. Figure 1 describes the framework followed, indicating the main interventions along the six principal segments of the millet value chains—namely, genetic diversity, selection and cultivation, harvest, value addition, marketing, and final use. The project's interventions were designed to build complementarities across different entry points of the value chain for reinforcing the delivery of specific outputs as well as for creating the self-sustainability of activities. Our approaches were also designed to promote linkages among stakeholders who are often disconnected: e.g., bridge gaps between researchers and development agents; bring farmers and user groups working together in PVS assessments in which both yield and use-related traits for household consumption and marketing were considered equally; build the capacity of farmers and SHGs in terms production of high-quality seed, cultivation practices, grain processing and other value addition tasks, as well as capacity in marketing (including branding) and production of more attractive food for household composition; strengthen and/or build community seed banks combined with processing units (Figure 2) where local varieties could be easily processed for domestic or market use; raise awareness about the nutrition, income, and

resilience benefits of millets among all stakeholders, from growers to policy makers (see outcome on policy work later in the paper).

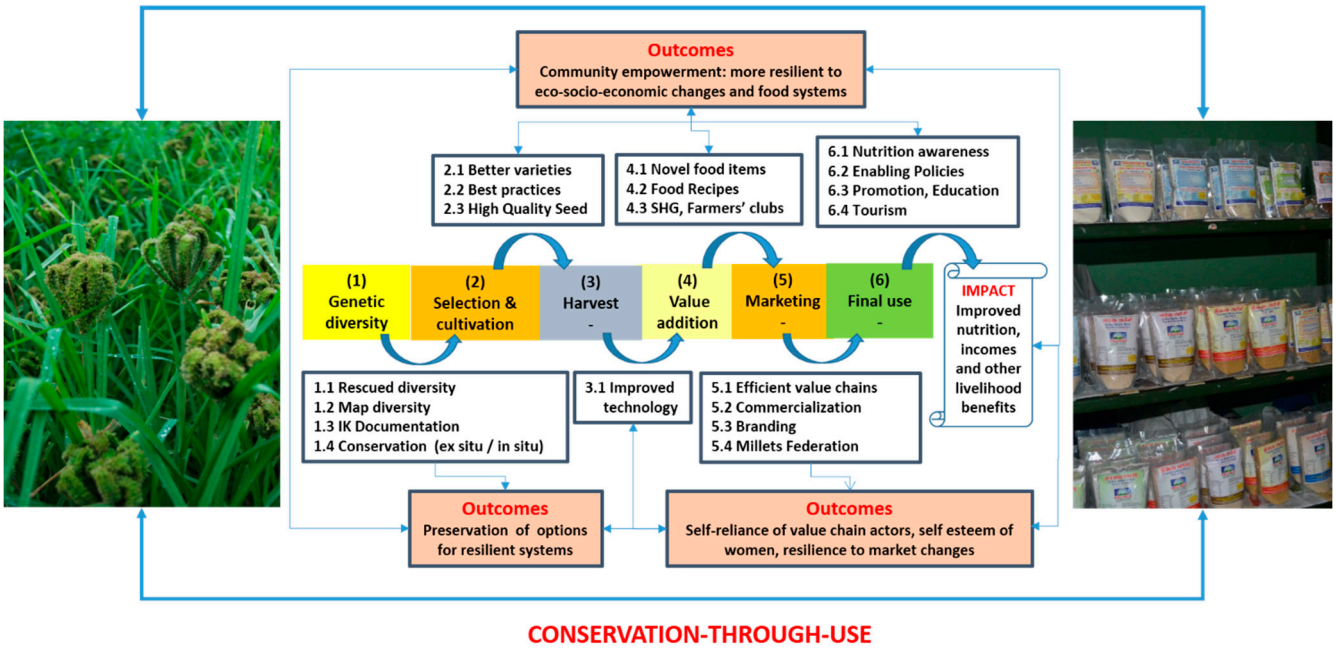

Figure 1. Millet holistic value chain approach.

Figure 2. Opening ceremony for the value addition cum conservation units in one of the project sites of Kolli Hills in 2012 (S. Padulosi of Bioversity International and Rima Alcadi of IFAD taking part in the inauguration of the facilities).

Table 1 lists methods and tools newly developed and/or deployed in the project along with major achievements resulting from their application; stakeholders involved in these activities are also mentioned to highlight the interdisciplinary and inter-sector synergy the project has been seeking throughout its implementation.

Table 1. Methods, tools, and key achievements in the holistic value chain approach for minor millets in India.

Relevant value chain portion of application	**Methods and tools deployed/developed**	**Stakeholders involved**	**Key achievements**
Genetic diversity	• Survey and collection of target crop diversity *in situ* (via Focus Group Discussions, base line surveys)	MSSRF, Communities, SHGs, farmers' clubs, women's associations	Understanding of existing diversity on farms; access to wider genetic diversity by user groups (in Kolli Hills: finger millet 7, little millet 8, Italian millet 7, kodo millet 1; in Jeypore: Finger millet 7, little millet 2)
	• Map out existingcrop diversity, assess threats and vulnerability status (via Focus Group Discussions, base line surveys)	MSSRF, Communities, SHGs, farmers' clubs	Distribution maps of crops and varieties; status of conservation and use; status of vulnerability and loss
	• Introduction of varieties from *ex situ* genebanks	MSSRF, ICRISAT, Communities, SHGs, farmers' clubs, women's associations	Availability of wider basket of diversity options to farmers
	• Participatory documentation of useful traits (Focus Group Discussions)	MSSRF, Communities, SHGs, farmers' clubs, women's associations, value chain actors	Identification of traits useful for cultivation and use by HH and markets. Through PVS farmers observed best varieties giving high importance to visual traits such as panicle size, number of panicles-bearing tillers, number and size of fingers in finger millets, grain size, color, overall yield, and time of maturity. Scientists observed in particular the following: days to flower, grain yield (kg/ha), fodder yield (kg/Ha), grain color, filling quality.

Table 1. *Cont.*

Relevant value chain portion of application	Methods and tools deployed/developed	Stakeholders involved	Key achievements
	• Conservation *ex situ* and *in situ* (on farm), via creation/strengthening of SHGs and farmers' clubs	MSSRF, SHGs, farmers' clubs, women's associations, custodian farmers, community gene banks	Conservation of crop diversity as key asset for building resilient livelihood systems
	• Organize seed/food fairs for exchange of seeds and knowledge among users (via engaging SHGs and local authorities)	Communities, local leaders, SHGs, farmers' clubs, women's associations, value chain actors	Exchange of seeds and IK among users which also helps safeguard a community's identity and food culture associated to nutritious millets
	• Train trainers on new methods and tools in target communities	MSSRF, Universities of Bangalore, Dharwad, and Uttarankad, communities, SHGs, farmers' clubs, women's associations, value chain actors	Strengthening skills of user groups—esp. women and vulnerable groups—in conservation practices and use enhancement of millets; training in the area of: seed collection, PVS, quality seed production, seed bank management, agronomic techniques, using farm tools to minimize drudgery, use of processing equipment, value addition methods, and product development and marketing.During 2008 alone, 75 training days were organized and 1399 trainees including 824 women were trained. Similar training programs were conducted every year under this project at all locations.
Selection and cultivation	• Participatory Variety Selection (PVS)	MSSRF, Universities of Bangalore, Dharwad, and Uttarankad, communities, SHGs, farmers' clubs, women's associations, value chain actors	Selection of varieties (HYV or landraces) showing best yields and best traits (in terms of cultivation, processing, and food preparation)

Table 1. *Cont.*

Relevant value chain portion of application	Methods and tools deployed/developed	Stakeholders involved	Key achievements
	• Production of high quality seed of selected varieties	MSSRF, communities, SHGs, farmers' clubs, women's associations	Availability of high-quality seed of selected varieties to farmers; high-quality seed of the varieties selected through PVS was produced and distributed to farmers in 2007 (291 kg) and 2008 (2.8 tons). In 2009, more than 10 tons of high-quality seed of improved varieties of fiv minor millet species across all the project locations were produced and transferred to respective village seed banks to support the use of target species in the local communities. Among the selected ones 60 metric tons of quality seeds produced in the year 2003 and 2004. Among the varieties distributed: Sukshema (32 tons), HMT 100-1 (110 tons), and GPU 28 (eight tons).
	1. Enhancement of agronomicpractices (e.g., change of crop distances in planting, crop rotation, introduction of mechanical weeding, crop rotation, vermicompost)	MSSRF, Universities of Bangalore, Dharwad, and Uttarankad, communities, SHGs, farmers' clubs, women's associations	Reduction of drudgery in cultivation of millets
	2. Train trainers on new methods and tools in target communities	MSSRF, communities, SHGs, farmers' clubs, women's associations	Enhanced skills of farmers in cultivating millets. Skills in using machinery, product development, andmarketing are the new dimensions in the lastdecade. Across sites, several families are involved in value addition and marketing of millets,with new opportunities emerging in the hills and plains. New products reach the markets. Private initiatives are booming.

Table 1. *Cont.*

Relevant value chain portion of application	Methods and tools deployed/developed	Stakeholders involved	Key achievements
Harvest	3. Improvement of harvest improvement methods	MSSRF, communities, SHGs, farmers' clubs, women's associations	Reduced drudgery and grain loss in post-harvest operations. Finger millet crop matures in about 95–125 days depending on the variety used, the crop season, and the method of cultivation. Traditional harvesting method: At maturity, the stem turns a straw color and the ears turn a brownish color. Plants are cut to ground level using sickles, left in the field for drying for 3–5 days, tied in bundles, and either stacked in the field itself or transported to the threshing yard and stacked there. Alternative harvesting method: cut and remove only the ears from the plants, dry them thoroughly and thresh by beating with sticks or tread using a tractor or stone roller. No effective machineryis available for harvesting and threshing operations.
Value addition	4. De-huller machine (specify target species and level of efficacy); Pulverizer machine(specify target species and level of efficacy)	MSSRF, Universities of Bangalore and Dharwad,communities, SHGs, farmers' clubs, women's associations	Reduced /elimination of drudgery in processing millets
	5. Development of enhanced food preparations and novel food recipes	MSSRF, Universities of Bangalore and Dharwad,communities, SHGs, farmers' clubs, women's associations, schools, and hospitals	Easier food preparation that eliminates drudgery and produces food items more attractive to younger generations and modern lifestyles. Value-added products include: Finger Millet Malt (Ragi Malt), Thinai Payasa Mix, Samai Bajji Mix,Samai Uppuma Mix, Samai Rava Dosa, Mix Little Millet rice, Italian Millet rice, Finger Millet Flour Buns, muffins, cakes, biscuits,popping recipes, "diabetic mix"

Table 1. *Cont.*

Relevant value chain portion of application	Methods and tools deployed/developed	Stakeholders involved	Key achievements
	6. Creation of SHGs to manage community-based processing centers	MSSRF, communities, farmers' clubs, women's associations	Enhanced capacity of communities in processing and using millets for domestic or market uses
Marketing	7. Strengthening of cooperatives for marketing products via creation/strengthening of SHGs	MSSRF, communities, farmers' clubs, women's associations	Enhanced capacity of communities in marketing millets,market orientation, exposure visits to different streams of markets,provision of market information through information and communication
	8. Train trainers/SHGs on new methods,tools and practices in target communities (incl. packaging, branding and ways to obtain Government's required certificates for marketing)	MSSRF, communities, SHGs, farmers' clubs, women's associations	Enhanced skills of SHGs in marketing tools and entrepreneurship for millets. Kolli Hills Natural Foods Brand; SHGs received legal certificates, Small Scale Industries certificates, Quality Control Certificates, Food Safety Standards authority of India certificates.
	9. Building platforms and linkages among actors of value chains (incl. with restaurants)	MSSRF, communities, SHGs, farmers' clubs, women's associations.	Building sustainability measures in support of enhanced use of millets; linkages with mainstream markets;food world supply chain of actors; establishment of producer groups; deployment of distributor branding for products; product diversification; identification of niche markets; market assessments supply and demand studies; interest free loan support programs; infrastructure development and management skills development

Table 1. *Cont.*

Relevant value chain portion of application	Methods and tools deployed/developed	Stakeholders involved	Key achievements
Final use	10. Collection of traditional food recipes and dissemination of recipe books	MSSRF, communities, SHGs, farmers' clubs, women's associations	Popularization of drudgery-free and more attractive food preparations for nutritious millets; contribution in safeguarding food culture and identity. Recorded traditional recipes, documented as monograph. Some of the recipes promoted as marketable products.
	11. Food festivals, public campaigns,involving school children, religious groups, and policy makers (via fact sheets, articles in the press, TV interviews, *etc*.)	MSSRF, communities, SHGs, farmers' clubs, women's associations, schools, policy makers, religious groups	Popularization of nutritious millets esp. among younger generations and decision makers; introduction of a wider diversity of millets in religious offerings in temples. Folk theatre, road show, food festival, participation in conference. Organized several millet food recipe festivals.
	12. Promotion of millets in school feeding programs	MSSRF, Universities of Bangalore and Dharwad,schools, policy makers	Awareness raised in decision makers over the importance of millets in school meal programs
	13. Lobbying at the Indian Parliament for the amendment of the Food Security Bill	Prof. MS Swaminathan, other MPs; governments and other State officials	Awareness raised among key decision makers over the strategic role of millets in India (esp. for adaptation to climate change, nutrition security, and income generation) and key contribution towards the amendment of the bill through the inclusion of minor millets in the Public Distribution System (PDS).

By pursuing a range of activities simultaneously with a range of well-connected actors, the project was expected to improve social empowerment and income generation, to leverage the nutritional benefits of minor millets, and to contribute to the sustainable conservation of their genetic resources (for more on this approach and its rationale see Padulosi *et al.* [7]).

The research reported here took place as part of a global project on neglected and underutilized species (NUS) supported by the International Fund for Agricultural Development (IFAD) and the European Union. This project was the first United Nations-supported global effort to enhance the use and conservation of NUS [8]. The project was coordinated at the global level by Bioversity International and implemented in India by the M.S. Swaminathan Research Foundation (MSSRF), Chennai; the University of Agricultural Sciences (UAS), Bangaluru; UAS Dharwad; G.B. Pant University of Agriculture and Technology (GBPUA&T), Hill Campus, Ranichauri; and the Central Food Technology Research Institute (CFTRI), Mysore. Implementation took place in 34 communities in four states (Karnataka, Odisha, Tamil Nadu, and Uttarakhand) with more than 750 participating households. Figure 3 shows the areas that have been targeted by the project.

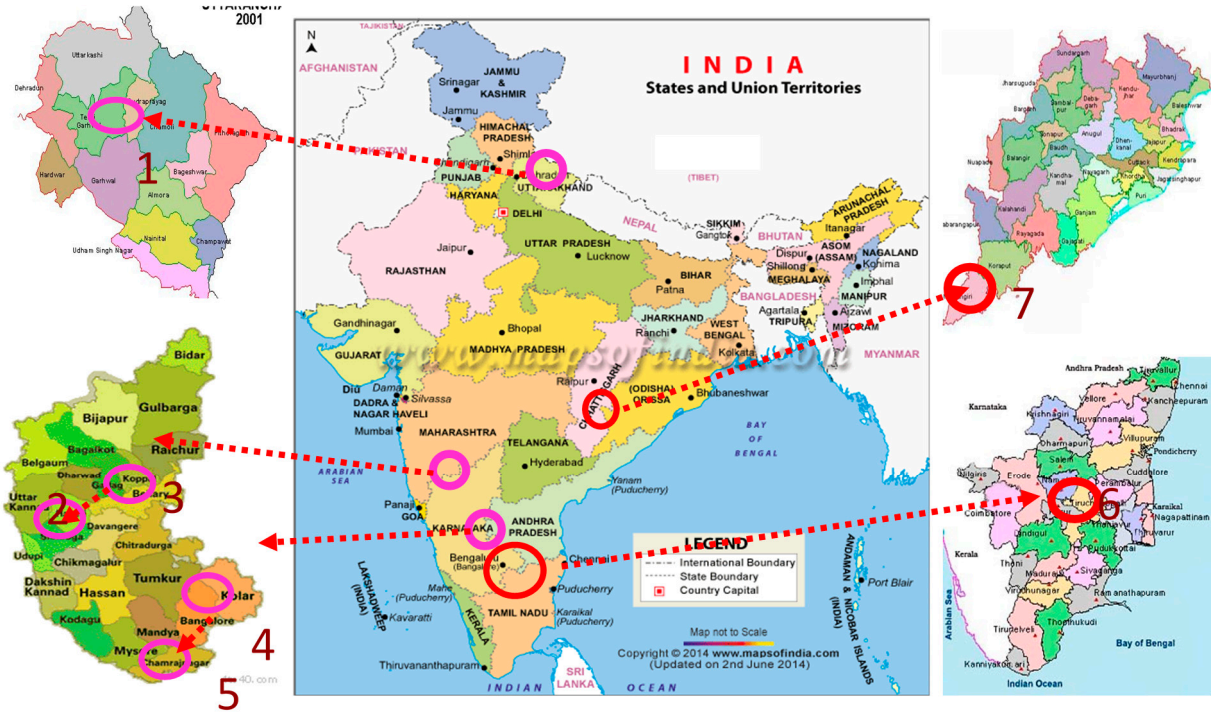

Figure 3. Project target areas (marked by red circles) across the four Indian states of Karnataka, Odisha, Tamil Nadu, and Uttarakhand.

2.1. Capacity Development

One of the main concerns of the project was to develop human capacities for the self-sustainability of those enhanced practices the project was going to introduce. To that regard, self-help groups and farmers' clubs (informal associations of farmers created by the MSSRF since the mid-1990s) [9], played a fundamental role in the methods testing phase of the project as well as in the dissemination of results and good practices. The benefits to members of these grassroots groups went far beyond growing and using millets. Groups elect a chair and secretary and conduct regular meetings to review progress, thrift,

and enterprise building, as a result setting the stage for increased self-determination and governance. Some groups started with members saving a little each day to build up group capital and establish group bank accounts, thereby becoming eligible for bank loans. As a result, small scale industries are gradually being established. Bank savings accumulated by self-help groups provide short-term loans to help members develop enterprises. The self-help and farmers' groups thus strengthen the human and social capital of those involved, promoting sustainability; their establishment was a key element in the project's exit strategy.

2.2. Gender

Another cross cutting element of the project was its focus on gender and in particular the exploration of ways to strengthen the empowerment of women whose level of marginalization in India's rural society is still very high.

The lack of attention paid to gender during the Green Revolution is an additional factor that can be linked to its failure to improve nutrition security in India. Those responsible for promoting the Green Revolution paid little attention to female-dominated traditional agriculture and knowledge. Women, in fact, were displaced from their traditional roles in agriculture, partly as a result of mechanization [10]. In addition, as a result of their different experiences and activities, women and men have different but complementary knowledge about plants and agriculture. This gender-differentiated knowledge is of great importance for the sustainable conservation and use of agrobiodiversity [11,12]. Women select the varieties that are most useful to their household and community, assessing detailed criteria such as taste, color, size, texture, cooking time, crop yield, ease of processing and access, grain formation, and resistance to pests and insects, all factors that promote resilience and food and nutrition security [13,14]. Men, on the other hand, select varieties according to criteria associated with the male's main responsibility, income generation, giving higher priority to high yield and good market price [15].

Women—who are perceived as lower in status—tend to have weaker control over household resources, tighter time constraints, less access to information and health services, poorer mental health, and lower self-esteem. Furthermore, resources controlled by women are more likely than those controlled by men to be used for items that benefit their children, such as food, clothing, and health care [16]. Women in poor households of India (and elsewhere) spend most of the income under their control on basic household needs, while men are more likely to spend on personal goods such as alcohol and tobacco [17]. Women also play a key role in determining which food to keep for home consumption and which to sell at local markets [11].

At the small and marginal farm holdings and household level, women' drudgery in production and lack of postharvest processing technology are the key factors for neglect of millets. Other elements include: lower profitability of NUS in cash terms per acre of land compared to alternatives available; requirement of more female labor for weeding; drudgery in pounding and lack of processing machines for little and Italian millets; weeding difficulties in intercropping with tapioca and absence of cattle for ploughing the land (specific to Kolli Hills). Drudgery in processing is indeed a major limitation for use of millets. All millets, with the exception of finger millet, are characterized by several layers of hard seed coats, which requires high abrasive force to remove. The traditional de-cortication process is a tedious physical process using mortar and pestle, almost exclusively carried out by women. The project

tackled drudgery removal as one of its key tasks and the solutions found had a very strong impact on women' empowerment, which underpinned the detailed delivery of almost all the activities, which sought to give women increased decision-making authority and increase their confidence in their decisions and opinions (see later in the text for more details on this work).

3. Results and Discussion

3.1. Conservation and Participatory Variety Selection

The decline in cultivation of minor millets has been accompanied by a loss of genetic diversity in the remaining varieties, many of which are not necessarily well adapted to the changing socioeconomic and environmental conditions in which they are being grown. To address this, concerted efforts were made to survey and collect existing varieties of minor millets and to train farmers to evaluate varieties and save high-quality seed. Effective conservation of agricultural biodiversity is vital for ensuring its sustainable use and requires *ex situ* and *in situ* methods to be sustainable over the long term [18]. Given the lack of priority from official and mainstream actors that results in crops becoming NUS, the need for sustainable conservation and use becomes even more important [19–21].

The project partners worked with local farmers to survey, document, and sample the genetic diversity of minor millets in Kolli Hills, Tamil Nadu (see Table 2), and Kundura, Odisha (see Table 3). Considering just little millet, the number of landraces, or farmer varieties, was almost identical in the two collecting areas.

Table 2. Local varieties of minor millets conserved by farmers in Kolli Hills, Tamil Nadu.

Species	No. of Varieties	Local Names
Little millet	8	Vellaperumsamai, Malliasamai, Sadansamai, Kattavettisamai, Karunsamai, Thirikulasamai, Perunsamai, Kottapattisamai
Italian millet	7	Perunthinai, Sentinai, Palanthinai, Killanthinai, Koranthinai, Karunthinai, Mosakkanthinai
Finger millet	6	Karakelvaragu, Arisikelvaragu, Krunmulian, Kelvaragu, Sattaikelvaragu, Perunkelvaragu, Sundangi Kelvaragu
Kodo millet	1	Thirivaragu

Table 3. Varieties of little millet conserved by farmers in Kundura, Odisha and their main features.

Variety Name	Main Features
Baunsha Ganthi Mandia	Short duration variety
Sana Mandia	Short duration variety (Sana means short)
Dashera Mandia	Medium duration variety, which matures duringthe Dashera festival in September–October
Janha Mandia	Variety preferred to intercrop with maize (Janha means maize)
Biri Mandia	Variety preferred for intercrop with black gram (Biri means black gram)
Bada Mandia	Long duration variety (Bada means long)
Athangula Mandia	Variety with head having eight fingers
Dashera Suva	Another variety that matures during the Dashera festival in September–October
Dashera Kala Suva	Black colored version of Dashera suva

All the landraces collected were conserved *in situ*, *i.e.*, locally in the community, and *ex situ* at the MSSRF Community Gene Bank in Chennai. In order to tackle farm conservation sustainably, the project worked to build enabling conditions for this practice across target areas and created incentives for farmers to continue maintain diversity. During its implementation period, the project worked with communities to disseminate better cultivation practices, introduce drudgery-free processing methods and tools, raise awareness of the nutritional values of landraces, boost the gastronomic appeal of local varieties through innovative recipes, and establish 15 community gene banks in 15 locations across 45 settlements over 15 years. These gene banks now help communities to conserve 21 varieties of minor millets, many of which are now used by SHGs and Growers' Federation through market-driven activities. Table 4 shows the quantity of seeds of millet crops that have been distributed to farmers by these community gene banks since 2001.

MSSRF has been instrumental in developing the concept of gene-seed-grain banks to address the twin problems of short-term food security and poor seed storage [22]. The gene-grain-seed bank is generally a purpose-built structure in the village that is designed to provide a safe environment for the storage of seeds. In the first place, it represents a local genebank to conserve locally important varieties. In the second, it also enables community families to store their harvest for later consumption, and to borrow from the community store rather than eat their stored seed. Finally, it is a safe place to store seeds saved specifically for the next crop cycle, and to make higher-quality seed available as a loan even to farmers who cannot afford to buy such seed.

A further evolution of the conservation-through use paradigm being promoted by MSSRF in Kolli Hills is the Village Millet Resource Centre (VMRC), which hosts processing units for millets as well as seed conservation stores. To date, some 15 VMRCs have been established across different "Panchayat" (municipalities), which serve numerous villages (settlements). Table 5 lists the established VMRCs and the crop diversity maintained in each of them.

Good quality seed encompasses the notion of seed suitable for local growing conditions. To ensure that farmers had access to suitable seed, the project undertook several activities under the rubric of participatory variety selection (PVS), which is well established as offering marginal farmers good opportunities to improve the genetic basis of their crops [23,24]. Where farmers who retain strong traditional knowledge and skill take part in PVS, this adds to their involvement in and ownership of the technology. Where farmers are weak, additional training provides them with supplementary skills and empowerment.

Locally available varieties as well as 6000 other accessions (landraces and/or improved varieties) obtained from ICRISAT, Pattencheru (Andhra Pradesh), the All India Coordinated Small Millet Improvement Project at the University of Agricultural Sciences (UAS), Bangaluru, and other institutions in India were deployed in the initial farmer participatory variety selection carried out at Kolli Hills (Tamil Nadu) and Jeypore, (Odisha) during 2002–2004. On elimination of several low yielding exotic and photosensitive accessions, the initial selection shortlisted 180 accessions. During the second selection cycle, 33 promising varieties (14 finger millet, 11 little millet, and eight foxtail millet) at Jeypore and 29 varieties (nine finger millet, nine little millet, and 11 foxtail millet) at Kolli Hills were identified by farmers as the best accessions. During the third cycle of selection, based on farmers' choice and critical agronomic data, the three highest ranking varieties in each of these millets were identified (Table 6).

Table 4. Millet seed transactions through the gene banks established by the project Kolli Hills during the period 2000–2001 to 2013–2014.

Millet *	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014
Little Millet	900	1389	453	508	510	95	7.5	16.5	56.5	306	298	176	197	432
Italian Millet	1089	987	357	435		279			18	55	150	63	81	353
Finger Millet			227	240		172			112.8	519	232	246	270	562
Kodo Millet		24				43			5	20	10	5	10	15
Proso Millet						27			5	11	10	7	15	35

***** Quantity of seeds distributed (kg).

Table 5. Village Millet Resource Centers (VMRC) in the Kolli Hills, with indication of their location, gender in management, and millet crop and varieties conserved.

Name of the VMRC, Settlement	Panchayat Name	Nearest Settlements Served by VMRC	Managing SHGs/FCs	Gender	Species and Varieties of Millets Maintained inEach VMRC				
					Little Millet	Italian Millet	Finger Millet	Kodo Millet	Proso Millet
Chinnamangalam VMRC	Alathur Nadu	1. Chinnamangalam 2. periyamangalam 3. Alaripatty	Ilamsittu Angal suya uthavi kulu	M	Kattavettisamai, Perumsamai, Karumsmai	Mookanthinai	Perungelvaragu, Karumuliankelvaragu	Nil	Nil
Alathur orpuram VMRC	Alathur Nadu	1. Mulakkadu 2. Orpuram	Orpuram womens Farmers club	F	Perumsamai, Kattavettisamai	Mookkanthinai	Sundangikelvaragu, Karakelvaragu	Nil	Panivaragu
Navakkadu VMRC	Bail Nadu	1. Navakkadu 2. Paraivalavu 3. Thotathuvalavu 4. Panankanni 5. Amnchikkadu	Maadhammal sangam	F	Nil	Nil	Suruttaikelvaragu, Perungelvaragu	Nil	Nil
Karamankadu VMRC	BailNadu	1. Nochikadu 2. Kalathuivalavu 3. Karamankadu 4. Pongampatty	Kolli malai suttru sulal padhugappor sangam	M	Sadansamai, Malliasamai	Peruthinai, Palanthinai	Karakelvaragu	Nil	Nil

Table 5. *Cont.*

Name of the VMRC, Settlement	Panchayat Name	Nearest Settlements Served by VMRC	Managing SHGs/FCs	Gender	Species and Varieties of Millets Maintained in Each VMRC				
					Little Millet	Italian Millet	Finger Millet	Kodo Millet	Proso Millet
Sulavanthipatty VMRC	Devannur nadu	1. Sulavanthi patty 2. Katakkadu	Pidariyamman suya uthavi kulu	F	Vellaperumsamai	Palanthinai, Perunthinai	Arisikelvaragu, Sattaikelvaragu	Nil	Nil
Aripalapatty	Devannur nadu	1. Aripalapatty 2. Aripalacolony	Kaaliyamman sutrusoolal pathugappor sangam	F	Vellaperumsamai	Perunthinai, Palanthinai	Perungelvaragu, Sattaikelvaragu, Suruttaikelvaragu	Thirivaragu	Nil
Adukkam VMRC	Sellur Nadu	1. Oormudipatty 2. Adukkampatty 3. kulipatty 4. Veeraganur patty	Adukkampatti girama munnetra sangam	F	Malliasamai	Palanthinai, Perunthinai	Perungelvaragu, Karakelvaragu	Nil	Nil
Vendalapadi VMRC	Sellur Nadu	1. Vendalapadi 2. Pinnam 3. Velarikadu 4. Kadamangalam	Sri ranganathar suya uthavi kulu	F	Vellaperumsamai	Perunthinai, Palanthinai	Perungelvaragu, Karakelvaragu	Nil	Nil
Thuvarappallam VMRC	Thiruppuli Nadu	1. Thuvarappallam, 2. Puthuppalayam, 3. Thenur colony	Mazhaichaaral munnetra sangam	F	Vellaperumsamai, Thirigulasamai	Perunthinai, Senthinai, Koranthinai	Perungelvaragu, Sundangikelvaragu	Thirivaragu	Panivaragu
Puliyampatty VMRC	Thirupuli Nadu	1. Puliyampatty 2. Perunkerai	Puliyampatti Magalir Suyauthavikulu	F	Thirigulasamai, Vellaperumsamai	Koranthinai, Perunthinai	Sundangikelvaragi	Nil	Nil

Table 5. *Cont.*

Name of the VMRC, Settlement	Panchayat Name	Nearest Settlements Served by VMRC	Managing SHGs/FCs	Gender	Species and Varieties of Millets Maintained in Each VMRC				
					Little Millet	Italian Millet	Finger Millet	Kodo Millet	Proso Millet
Padasolai VMRC	Thirupuli Nadu	1. padasolai 2. Kalari 3. puthuvalavu	Iyyanar porulathara munnetra sangam	M	Sadansamai, Vellaperumsamai	Senthinai, Perunthinai	Sundangikelvaragu, Perungelvaragu	Nil	Nil
Semputhuvalavu VMRC	Thirupuli Nadu	1. Semputhu 2. Naduvalavu 3. Melvalavu	Kannimar Magalir Suyavudhavi kuzhu	F	Vellaperumsamai	Senthinai, Perunthinai	Perungelavaragu	Nil	Nil
Periyakovilur VMRC	Valapur Nadu	1. Periyakovilur 2. Chinnakovilur 3. Assakkadu	Thayammal iyarkkai vali padhugapporsangam	M	Vellaperumsamai	1.sattaikelvaragu, Vellaperumsamai	1.sattaikelvaragu, Vellaperumsamai	1.sattaikelvaragu, Vellaperumsamai	1.sattaikelvaragu, Vellaperumsamai
Kuchikeraipatty VMRC	Valavanthinadu	1. Kuchikeraipatty 2. Solakkadu	Nanbargal Suyaudhavi kuzhu	M	All varieties	All varieties	All varieties	All varieties	All varieties
Thiruppuli VMRC	Thiruppuli Naddu	1. Thiruppuli 2. Pannanthurai	Thiruppuli Uzhavar Mandram	M	Thirigulasamai, Vellaperumsamai	Senthinai, Palanthinai, Perunthinai	Sundangikelvaragu, Perungelvaragu	Nil	Nil

Table 6. Varieties chosen through the Project's PVS activities carried out in Jeypore and Kolli Hills and key agronomic criteria used in the process.

Rank	Jeypore Site				Kolli Hills Site				
	Variety Selected	Days to Flower	Grain Yield kg/ha	Fodder Yield kg/ha	Grain Color *	Variety Selected	Days to Flower	Grain Yield kg/ha	Fodder Yield kg/ha	Grain Color *
Italian millet										
1	Bada Kangu (Local)	88	1149	7472	Lt Y	Senthinai (Local)	61	833	4668	R
2	ISE-809	53	932	6639	Lt Y	ISE-38	61	775	4625	Y
3	ISE-1269	53	1051	5694	Lt Y	TNAU-173	61	907	4458	Y
Little millet										
1	OLM-203	99	1283	3037	Lt Y	IMPR-393	55	695	3375	Lt gr
2	Kalakosla (Local)	109	1144	3759	Br	Kattavetti Samai (Local)	113	715	3400	D Gr
3	IMPR-393	71	950	2250	Br	Sukshema	64	650	3293	Gr
Finger millet										
1	GPU 49	82	2632	6046	Lt Br	IE-2863	87	1205	4875	Lt Br
2	Athangulia	90	2429	6139	R	GPU-49	64	1225	4093	Lt Br
	Mandia (Local)					VHC3880	57	793	3743	Pl Br
3	IE-3093	86	1727	4694	Lt R	IE-3023	87	763	2968	Pl Wh

***** Y—yellow; Lt Y—light yellow; Gr—grey; D Gr—dark grey; Lt Br—light brown; Pl Br—pale brown; Wh—white; Lt R—light red; R—red.

The strategic importance of PVS can be seen in the observation that while farmers in Kolli Hills preferred finger millet varieties with mid-early or medium maturity, the Jeypore farmers by and large preferred late maturing varieties, consistent with the different pattern and distribution of rainfall at these two locations. While confirming the value of PVS specifically for NUS, in view of their localized cultivation, these activities also helped to confirm the agronomic superiority of some of the locally-adapted farmer varieties compared to improved types, as well as the identification of some improved varieties that were superior to local varieties, thus giving the participating farmers an improved selection of varieties, regardless of the origin of those varieties [25,26]. Farmers decided which of the varieties to propagate and conserve in the village gene-grain-seed bank.

A second aspect of good-quality seed, in addition to suitability for local conditions, is to ensure that farmers have access to sufficient seed that is biologically sound. The project therefore placed considerable emphasis on the production of high-quality seed as well as on training farmers in the maintenance of variety identity and safe seed storage. Training efforts for genetic purity focused on variety characterization and especially the maintenance of varieties by seed selection and roguing off-types. Training also imparted good practices for seed handling during harvest, threshing, drying, and storage. As a result of this training, the amount of high-quality seed available to farmers increased steadily during the project timeframe. For example, 291 kg of high-quality seed was produced by and distributed to participating farmers in 2007, increasing to 2.8 tons in 2008 and more than 10 tons of high-quality seed of the five minor millet species in 2009. The project also demonstrated that the availability of quality seed and improved agronomic practices helped in enhancing the productivity and production of small millets.

3.2. Improving Yields

PVS was itself instrumental in improving yields. In addition to yield observations, pre- and post-harvest focus group discussions with the farmers unearthed some of the characteristics important to them in identifying superior varieties. For little millet, grain and fodder yields were the most important characteristics, the latter a quality sometimes overlooked by mainstream breeders. Other important characteristics included crop duration, panicle type and size, disease resistance, and drought tolerance; farmer appreciation for these qualities in the local and improved varieties was the basis of their selection. Women's participation in these group discussions was also helpful in guiding PVS with information regarding culinary aptitudes and cultural preferences [27].

In Karnataka state, for example, the varieties selected by farmers generally outperformed local varieties by a considerable margin (see Table 7 below) In Kundera, Odisha, farmers' rankings for their preferred varieties followed very closely the yields for those varieties in trial plots. Although an analysis of variance revealed no significant differences among the top 10 performing varieties, the top four all gave significantly higher yields than the best local variety (Badomania). The top five selected varieties of individual minor millet species showed similar yield increases when compared with a local check variety over multiple trial locations. For little millet the yield gain ranged from 28% to 74%, for finger millet from 4% to 50%, and for foxtail millet from 11% to 36%. In the Haveri district in Karnataka, field trials during 2008 showed a 41% increase in mean grain yield that could be attributed to the use of improved varieties [28].

Table 7. Participatory variety selection in Karnataka state (Kollar, Haveri, and Bellary districts). Five best-performing varieties compared with a common local variety.

Species	Variety	Grain Yield (Quintal/ha *)	Increase Over Local Variety (%)
Little millet	Sukshema	10.30	73.7
	TNAU 98	8.88	49.7
	OLM 20	8.32	40.3
	PRC	7.58	27.8
	Co 2	7.58	27.8
	Local	5.93	
Foxtail millet	HMT 100-1	15.35	36.4
	Krishnadevaraya	13.73	22.0
	TNAU 173	13.50	20.0
	Narasimharaya	13.15	16.9
	RS 118	12.46	10.7
	Local	11.25	
Finger millet	GPU 28	20.52	49.6
	L 5 1	9.90	45.0
	GPU 26	16.42	19.7
	MR 1	15.22	10.9
	Indaf 9	14.30	4.2
	Local	13.72	

* 1quintal is 100 kg.

A second component of efforts to increase yields was to improve agronomic practices. Farmers traditionally supply little or no fertilizer to the crop. Demonstration trials on farmers' fields indicated that supplementary doses of fertilizers or manure (including vermicompost, a value-added activity introduced to some of the communities) enhanced productivity of little millet and finger millet by around 17%. Farmers also tend to use higher seeding rates than those recommended by UAS Darwad, because this gives them a higher fodder yield. Demonstrations of lower seeding rates—10 kg ha^{-1} *vs.* 20–25 kg ha^{-1}—increased seed yield by almost 19% with a loss in fodder of 9%, which farmers found acceptable [28]. Line sowing and intercropping were also found to improve yields. For example, six rows of millet (little, finger, or foxtail) with two rows of pigeon pea (*Cajanus cajan*) proved to be more productive and more profitable than traditional broadcast intercropping systems. Overall, data from 198 field trials in 2003–2004 indicated that improved cultivation practices contributed to an increase of 40% to 63% in grain yield and 34% to 47% in fodder yield over traditional practices [25,29]. Kundura village took part in 48 trials in six participating communities, seven of the trials exclusively involving women farmers. Yield increases compared to traditional practices, obtained from a package of interventions including quality seed, line sowing, modest manuring, and weeding ranged from 39% to 172%. Farmers achieved up to double their previous income, notably from the addition of pigeon pea and horse gram (*Macrotyloma uniflorum*) as intercrops. With regard to the costs of the introduction of improved practices, the cost-benefit ratio analyses carried out by the project revealed that cost of cultivation using farmers' practices and improved practices varied across farmers and field sites. In 2004, for example, the cultivation cost of intercrop system according to farmers' practice varied from Rs.

7632/ha ($141.3 @ $1 = Rs. 54) in Kolli Hills to Rs. 18,542 ($343.4) per ha in Jeypore. The cost-benefit ratio analysis showed that the average net income from finger millet intercropped with soybean grown under improved organic methods (Rs. 13,735/ha) was substantially higher than that of similar intercrop grown under traditional organic farming practices (Rs. 7397/ha). The results from intercropped barnyard millet also followed the similar trend although the net income from improved as well as traditional organic farming methods was relatively lower than that from finger millet.

In the Kolli Hills, where one of the factors driving the decline of minor millets was adoption of cassava (*Manihot esculenta*) as a cash crop, efforts were made to trial intercropping finger millet in the cassava fields. These proved highly successful, enhancing incomes by 3.2% (in concert with other elements of the package).

3.3. Post-Harvest Processing

An important constraint to the wider use of millets among rural families is the effort and drudgery needed to convert the harvested grain into palatable foods. Traditionally, these tasks are performed by women (see earlier in the text), who thresh the grain with their feet, use a pestle and mortar to dehusk the grain, and then a stone quern to grind the grain into flour, all tasks that require time and effort. Women spend most of the day away from home laboring in the fields, so they prefer foods that are easier and quicker to prepare than millets [30,31].

Small-scale, easy-to-use mechanical grain-processing technology would undoubtedly lower some of the barriers to making greater use of minor millets and rolling out value chains based on millets. The project team sourced local prototypes of micro-mills to de-hull and polish Italian and little millet, but these did not prove to be cost-effective. UAS, Dharwad, McGill University, Canada, and the MSSRF then developed another prototype for little millet. This prototype dehulled millet grains very effectively, recovering 90% of the seeds. The mills were subsequently manufactured in Belgaum, Karnataka, for deployment to the project communities. Mills alone, however, were not enough. They had to be embedded in a matrix of supportive activities, such as organizing self-help groups (SHGs), largely of women, to manage the mills and then training them in processing and adding value. Small-scale machinery to remove stones, which might otherwise damage the mills, was also deployed to improve post-harvest processing. There remains a need for polishing facilities to allow little millet and Italian millet to be consumed in the same way as rice, which communities prefer.

Larger-scale mills have also been an important component of value-added chains. In the village of Kaudiaguda, Orissa, the local SHG contributed labor and money to construct a shed to house a larger mill. The land for the mill shed was provided free of cost by the local Panchayat [32], a clear sign of the community's tangible appreciation of the improved livelihoods brought about by the project. This mill processes grain for three villages and the SHGs based there and generates income each month for the SHG that manages its operation. Several other villages throughout the project areas have adopted similar plans to house larger mills and provide a service to SHGs in neighboring communities. One difficulty in many villages is that while they may be able to manage and use larger diesel-powered mills, they are not connected to the electricity grid and hence cannot make use of electric micro-mills to reduce drudgery for farm women. The project has made an effort to convince the government to provide electricity to these villages.

At a purely personal level, whereas it took women about two hours to process sufficient millet for the daily needs of their families using traditional methods, the new micro-mills perform the same task in 5–7 min or less. The micro-mills did far more, though, than merely cut drudgery and processing time. Many women reported greater social status and self-esteem, and the reduced time and labor required to prepare minor millets opened up opportunities for them to earn extra income, strengthening their independence and financial security. Training in the production of value-added products was offered on the campuses of UAS, Bangaluru and UAS, Dharwad, usually the first time the SHG women traveled outside their villages. The training experience gave them additional confidence and skills to discern which of the value-added products are appropriate for domestic use and which for commercial development. All of these factors contributed to the empowerment of rural women; their slow transformation from housewives and farm laborers to market-based product developers and entrepreneurs has huge social implications.

As noted earlier in the paper, drudgery in processing is a major limitation for use of millets. All millets, with the exception of finger millet, are characterized by several layers of hard seed coats that require high abrasive force to remove. The traditional de-cortication process is a tedious physical process using mortar and pestle, almost exclusively carried out by women. The Federation, with the technical backup of MSSRF, facilitated the establishment of hullers and pulverizers suiting different types of millets, to cater to as many households as possible. The intervention has meant a lot, especially to women, who are now able to carry out processing with less fatigue and significant saving of time, which is now used for other activities. The Federation exposed women SHG members on training courses dedicated to value-added product development, quality standards, packaging, labeling, and marketing. Training in value addition helped women enhance their skills in production of products like malt, rava, and ready-made mixes of millets that fetch additional income. The Federation recognizes women's leadership in social and legal empowerment and creates an equal platform for mobility, skills building, group and market participation, decision making, and contribution in conservation through use. Over a period of twelve years (2001–2013), the cultivation, procurement, value addition, diversification, and sale of products have generated a gross income of 30,900 USD. Interesting facts related to the Federation over its ten years of activity in Kolli Hills include: a total of 109 groups involved (16 men, 30 women, one mixed, and 62 farmers' clubs); membership of 985 males and 526 females; groups managing nine pulverizing mills and three de-husking and flour mills; organic produce collection centers and community-based value addition units each at three locations; village millet resource centers at 16 locations; community-based natural food shops at two locations and a total financial turnover of 9,229,913 Rs. The Federation ("*Kolli Hills Agro Biodiversity Conservers' Federation", KHABCoFED*), has built an asset of agricultural machineries and value addition units along with a procurement centre whose value is estimated at 53,000 USD. Additionally, a savings of 75,000 USD has been set aside, which stands as a clear testimony to the success of this collective endeavor and a proof of the strategic role that underutilized crops like millets and associated natural resources can play in the livelihoods of people.

3.4. Nutrition

Despite the gains of the Green Revolution, malnutrition remains a severe problem in India, especially among rural people but also among the newly urbanized, where the double burden of over- and under-nutrition may coexist in the same family; see, for example, Ravishankar [33].

One of the primary benefits that millets offer is better nutrition. As a group, minor millets are high in a range of micronutrients, particularly calcium, iron, and dietary fiber. While protein levels are comparable to other staples such as wheat, rice, and maize, the balance of essential amino acids is better, and so they may offer more usable protein. Millet grains are also rich in important vitamins such as thiamine, riboflavin, folic acid, and niacin. Minor millets have a low glycemic index and thus do not contribute to disorders of sugar metabolism. They also contain other phytochemicals, including antioxidants, that are associated with health benefits (for details, see Yenagi *et al.* [34] and Bhag Mal and Padulosi [3]). For all these reasons, millets can play an important role in food and nutrition security, and not only for the poor. In fact, M.S. Swaminathan has said that they should be referred to as nutritious millets rather than minor millets [35].

To promote the nutritional value of millets, the project focused on direct use among the project participants and on creating markets for millet-based products in urban centers. Micro-mills (see above) proved a key element in promoting domestic consumption as they reduced the time women needed to prepare millet dishes for their families. In the villages of Manthrodi and Timmapur (Karnataka), introduction of mills was associated with an increase in household consumption of 7% and 13%, respectively. The increase in household consumption was mirrored across all project sites, with 69% of women reporting that millet had become a staple food for consumption [28].

In general, people find millet-based foods very acceptable. For example, in one pilot study, 80% of people favored breakfasts made of little millet, and 62% said they ate such foods regularly. This suggests that the decline in millet consumption can be reversed.

Schools were a primary target for nutrition interventions, because staving off the effects of malnutrition in young children has such great cumulative benefits in later life. Project nutritionists developed four low-cost nutritional meals from millets for the school feeding program of the government's Department of Women and Child Welfare, and millet-based products are being considered for school feeding programs in Karnataka State, which could benefit around 3.5 million children under six years old in the state. The study by Yenagi *et al.* [34] of millet-based dishes showed that while some millet recipes had the lowest cost per serving, they nevertheless provided the most calories and protein and were almost totally accepted by children participating in the test. Another study concluded that students fed with finger millet-based recipes were healthier, physically stronger, and studied more actively compared with a control group. Regular consumption of millets among children was associated with an incremental gain of 0.5% in height, 3.4% in body weight, 15.4% in hemoglobin level, and 37.8% in physical fitness index [36].

Similarly, promoting the use of millets in canteens, hospitals, and work places is another promising approach to improved nutrition among people who need it most. Millet research in the area of value addition has extended its scope to enter the food industry as novel foods, health foods, snacks, fermented breakfast foods, and bakery products. Thermal processing of millets has the advantage of extending the shelf life of grains with nutritional benefits. Processed millet can enter into the realm of therapeutic foods

through designing health foods based on the functional properties of millets. Thermally processed millets can easily enter into the PDS system/school feeding programs/hospital catering system as ageing and thermal processing of grains enhances the nutritional benefits.

Promoting the use of millets in canteens, hospitals, and work places appeared very promising also as people could better benefit from the energy contained in these crops. A study of five healthy persons under the age group of 45–50 years showed that the glycemic index among the subjects ranged from 35.20 to 57.20 in the case of little millet and 65.2–75.25 in the case of rice. These results confirmed that the slow release of glucose from millet food is quite beneficial for diabetics as the satiety value for such products would be high. According to the classification of the World Health Organization (WHO), little millet rice with a low glycemic index (47.23), as compared to rice with a high glycemic index (71.87), proved better in the management of diabetes and associated cardiovascular problems.

Type 2 diabetes is a complex metabolic disorder associated with developing insulin resistance, impaired insulin signaling, beta cell dysfunction, and abnormal glucose and lipid metabolism. These metabolic disorders lead to long-term pathogenic conditions including micro- and macro-vascular complications, neuropathy, retinopathy, and nephropathy. Millet has been shown to be potentially beneficial in the management of diabetes because of its high fiber content and slow digestion; moreover, it is a good source of B vitamins and contains substantial quantities of several minerals including calcium, iron, potassium, and manganese. Millet is featured in healthy foods for its ability to decrease insulin resistance and the low risk of diabetes may be related to foods with high content of phytochemicals, high antioxidant capacity, and polyphenolic compounds.

3.5. Product Development

The general acceptability of millet-based foods was seen as an opportunity to promote more nutritious snacks to urban populations at the same time as enhancing incomes and driving empowerment among millet farmers, thus adding to the role of millets in rural families. However, linking producers to markets is a greater challenge than both increasing yield and adding value to minor millets. Chains linking production to consumption are both fragile and dynamic. They are fragile because they are made up of many co-dependent stakeholders and many of these stakeholders—women and men—have limited time to spare from their farming and domestic work for building consortia. In India, SHGs (self-help groups) are key links in value chains but no SHG can span the entire consumption pathway. For that reason in our holistic value chain approach we needed to devote special attention to promoting networking and collaboration among partners with complementary skills, and nowhere was this more necessary than in the development and marketing of millet-based products.

Food technologists of the Home Science Departments of UAS Bangaluru and UAS Dharwad developed a range of novel products including savory and sweet snacks, noodles and other forms of pasta, muffins, and cookies. Other products included a malt drink made from malted finger millet that was developed at Kolli Hills, which became very popular in neighboring towns. Marketing of millet-based products was also boosted by working with participants to create more attractive packaging and labeling and developing recognizable branding for the communities producing the products. The “Kolli Hills” brand of nutritious millet products was successfully launched by the MSSRF and a trademark was filed at the India Patent Office.

These efforts paid off for the communities. Cost-benefit analyses showed returns varying from 130% to 215%, depending on the product and the location. Incomes of community members increased as a result. For example, three SHGs in Kolli Hills earned about 2200 USD in 2008 from the sale of millet-based products and one participating SHG in Jekinkatti, Karnataka, won a contract to supply millet for the school feeding program. Apart from contributing to enhanced income, making value-added millet-based products also generated additional employment, particularly for women, to the tune of 140–300 person days for every ton of grain processed [37].

At the intersection of school feeding programs and commercial products, a small survey by students of Rural Home Science at UAS Bangaluru revealed that more than 50 different kinds of product are on sale near schools—urban and rural—at a cost of one rupee a piece. This potential encouraged SHGs to develop more than 30 millet-based items aimed specifically at this market, including different types of fried snacks known as frioms (kachri), cookies, breads, and drinks.

The Federation facilitated the establishment of hullers and pulverizers suiting different types of millets, to cater to as many households as possible. The intervention has meant a lot, especially to women, who are now able to carry out processing with less fatigue and significant saving of time, which is now used for other activities. The Federation contributed to develop and strengthen the skills of women SHG members in value chain activities through hands-on training courses focusing particularly on enhanced processing methods.

All the efforts to promote value-added procedures in the communities have been supported by efforts to ensure that they are sustainable beyond the life of the project. For example, the manufacturer of the mills used by the communities was invited to provide basic training on mill maintenance and safety measures. In Kolli Hills, Tamil Nadu, SHGs for women and for men came together as the Kolli Hill Agrobiodiversity Conservers' Federation, with the support of the project. The Federation is now producing 11 value-added millet-based products and marketing them across Tamil Nadu state under the name of Kolli Hill Natural Foods. During 2013–2014, 7.8 tons of millet value-added products were sold by the Federation, earning an overall gross income of almost Rs. 615,000 (approx. 10,000 USD).

One consequence of the increase in production and marketing of value-added minor millet products is that as a small-scale industry it requires government approval for the operation of the production units. Project teams worked with rural communities to obtain the necessary certificates from the Department of Small Scale Industries, Tamil Nadu.

3.6. Tourism

During focus group discussions and stakeholder meetings held by the project, tourism was identified as another interesting option worth exploring for adding value and creating incentives for millet growers. Spiritual tourism was seen as an opportunity to promote minor millet products both as part of the *prasadam*, or sacred offerings, at Hindu temples and in their own right to tourists and pilgrims as nutritious products. These efforts were focused around Ranichauri, Uttarakhand, where the government launched an initiative to introduce minor millets (and amaranth) for *prasadam*. Project partners targeted shop keepers to raise their awareness of products made by local SHGs and the economic benefits to local farming families, and this proved effective in increasing the sales of offerings made of minor millets. The temples that were the focus of these efforts have spiritually important periods each year (such as

Ram Navami day at Surkunda Devi temple and Vijaya Dashami day at Rajrajeswari temple) when the flow of pilgrims to the temples is much greater, offering scope to market millet-based products and promote the nutritional benefits of those products. This is an approach that could be extended beyond Ranichauri.

3.7. Policies

A central pillar in our holistic approach is represented by policies essential in supporting scaling up of best practices and pursuing wider impact beyond project's target sites. No matter how much rural farmers and their communities may come to value minor millets, these crops will not receive official support without changes in the policy environment; one of the greatest challenges is to convince decision makers that minor millets deserve a place in mainstream agricultural, nutritional, and food policies. Some of the changes required could be simple. Mills, for example, need a reliable supply of electricity at a price rural communities can afford, which may mean rebalancing subsidies on different forms of energy and fuel. Other changes, such as making millets an accepted component of school feeding programs, may need more complex, coordinated changes among many actors. Beyond school-feeding programs, there is also a role for millets in national and local government public distribution systems to support vulnerable groups of people. As a result of dialogues with senior policy makers at meetings and workshops in which the project actively contributed through the MSSRF, the Indian Government has now included millets in the public distribution system in places where these crops are produced and there is a traditional preference for them. The Food Security Act 2013 entitles priority households to 5 kg food grain per person per month and eligible households to 35 kg per household per month [38]. Between them, these categories of household cover up to 75% of the rural population and up to 50% of the urban population who could benefit from the provision of minor millets. We believe that the Indian government's Food Security Act represents a robust example that can be replicated in other countries.

A second set of policy issues concerns the ways in which formal private and public sector agricultural entities consider millets. As an example, the formal seed supply sector is non-existent for minor millets, which is why one project focus was on strengthening the ability of communities to produce and distribute high-quality seeds. The scarce interest in millets (and in general in NUS) in the private sector is of high concern for the future of a well-fed planet. We argue that greater investment in nutritious local crops would help strengthen agricultural production and adaptation to unforeseen climate changes, and at the same time reinforce food and nutrition security in periods of socioeconomic uncertainty and shocks (such as those recorded in 2008). We also believe that greater awareness of consumers about diet diversity for healthier lives is a powerful element that private companies could leverage in including NUS in their market strategies, from seed production to the whole agri-food chain and strategies for distribution of millet based products to all segments of the population. Cultural relevance, new flavors, and innovation in food preparations are among the other interesting factors that would support a "pro-NUS" diversity-rich strategy of the private sector [6].

It would be helpful if the government and other parties concerned increased investment to develop superior varieties of minor millets and appropriate processing technologies, along with enabling policies to support their dissemination and adoption by consumers. At present, the government allocates considerable funds to support research programs on the major cereals such as rice and wheat. Diverting some of the allocated fund to millets would have additional spin-off benefits, such as contributing to the

more resilient production systems that will be needed to cope with predicted changes to the climate, as well as possibly mitigating the impact on climate change of existing production systems. Farmers would respond to a government support price by increasing their plantings of millets. More resilient local production systems can also help to buffer poor people and governments against external shocks such as the commodity price spikes of 2008 [29]. Government support is also needed in order to transition away from the donor-supported efforts reported here in order to move towards greater impact beyond project pilot areas.

4. Conclusions

The effects of minor millets on incomes and, especially, the empowerment of women cannot be overestimated. The vast majority of India's population is so poor that they cannot afford even the least expensive balanced diets [39]. Most smallholder farmers, in India as elsewhere, are net food buyers, which means that increasing their disposable income is a crucial path to better nutrition. The lessons learned through this multidisciplinary research effort amply demonstrate that currently marginalized crops, such as minor millets, can in fact contribute to the nutrition security of rural and urban poor people in India, while at the same promoting economic development and the empowerment of women and other vulnerable groups. The case of minor millets presented here is in fact just an emblematic case. India and many other countries are endowed with hundreds of nutritious crops whose research and development is still poorly addressed. Enhancing the use of these neglected crops is thus a powerful way to contribute to nutrition security and at the same time increase the development of vulnerable people.

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Author Contributions

Stefano Padulosi is the global coordinator of the IFAD Project whose work has been described here; he has led the preparation of the paper; Bhag Mal, provided assistance in gathering project data and reviewing contributions from all authors; Oliver I. King, is the coordinator of MSSRF's activities of the Project and contributed to the development of the paper; Elisabetta Gotor assisted the Project on the impact evaluation and contributed to writing its dedicated section in the paper.

Conflicts of Interest

The authors declare no conflict of interest.

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