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Research for agricultural development in support of nutrition sensitive agriculture – experiences from Ethiopia

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1. Introduction

In Ethiopia, approximately 90 percent of the country's 7.15 million stunted children under 5 live in rural areas [1]. Given that 67 percent of the population practises agriculture, there is significant interest by both researchers, governments and non-governmental organizations as to how to make agriculture more nutrition sensitive [2].

While rates of undernutrition in Ethiopia have declined substantially in the last 16 years, rates of stunting in children 6–59 months still hover around 40 percent in rural areas, and undernutrition in adult women (BMI<18.5) has remained around 20 percent [3]. Micronutrient deficiencies, especially of vitamin A, iodine and zinc remain a key public health concern [3].

While nutrition is a multisectoral issue, and malnutrition is driven by a wide range of factors including access to health care and sanitation, poor dietary diversity remains one of the critical factors leading to poor nutritional outcomes in Ethiopia [4]. Children in Ethiopia consume the least diversified diets of anywhere in Sub-Saharan Africa [5]. A range of studies from around the country have found that rural women also consume diets with very low levels of diversity, linked to high seasonal variation in access to different foods required for a healthy diet [6].

Adequate nutrition is important for health and immune function, which has become increasingly important in light of pandemics such as COVID-19. Additionally, having a healthy and well-nourished population also brings economic benefit. It has been estimated that Ethiopia loses 16 percent of its Gross Domestic Product each year as a result of poor nutrition [7]. Improving nutrition, especially for young children and women of reproductive age, can increase individual educational outcomes, leading to increased earning and reduced spending on health care [8–10].

Nutrition is a key priority in Ethiopia's Ten Years Development Plan, which is supported by a number of policies specifically targeting improved nutritional intake, including the National Nutrition Program (2016–2020), The Ministry of Agriculture's Nutrition Sensitive Agriculture Policy (2016) and the Seqota Declaration, an alliance of relevant ministries committed to end child malnutrition by 2030. However, the translation of these policies into concrete plans and actions requires increased understanding of how agricultural projects can be made more nutrition sensitive.

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1.1. How can agriculture improve nutrition?

Nutrition sensitive agriculture can be understood as agricultural activities that seek to feed people well by increasing availability, affordability, and utilization of diverse, safe, nutritious foods and diets, aligned with dietary recommendations and environmental sustainability [11], shifting the focus from producing enough calories to producing a diverse range of foods which meet people's needs for both macronutrients (calories, but also fats and proteins) as well as micronutrients (vitamins and minerals).

Availability The relative unaffordability of nutrient dense foods is linked, in part, to low availability related to low levels of production, seasonality and perishability. Poor road networks and lack of market access mean that often home production is a priority to improve availability, although this is hampered by numerous constraints including lack of seeds, water and land, as well as challenges in accessing high quality extension services. Furthermore, evidence from a range of studies in multiple geographic areas indicates that it is highly unlikely that households will be able to achieve nutrition security through home production alone, suggesting that other strategies are needed, including supporting commercial production of nutrient dense foods [12].

In rural Ethiopia, markets are underdeveloped, which is a particular challenge for nutrient dense foods that tend to be highly perishable (fruits, vegetables, milk) [1]. Studies have found that access to markets is an important factor in shaping both diets as well as influencing the relationship between production and dietary patterns [13]. Market access is also an important precondition for nutrition messaging to have an impact on diets. In Ethiopia, even households practising subsistence agriculture still purchase a significant portion of their food, on average 42 percent of overall calorie consumption. The majority of food which increases dietary diversity (over 80 percent) comes from the market, purchased mainly using income from farming activities [14]. This important role of markets in ensuring household level dietary diversity is seen across seasons, as well as types of households (wealthier and less wealthy) [14]. This link between increased dietary diversity through purchase, rather than own production is also seen in similar contexts for example ultra-poor households in Kenya; where it was found that poultry ownership increased consumption of multiple food groups, not just chicken and eggs, suggesting increased dietary diversity was more likely caused by increased incomes [15]. The evidence for agriculture as a means of income, which can be used by the household to purchase food and non-food items, to improve nutrition outcomes, is mixed and nuanced. On the one hand, simply improving household income, especially without a focus on promoting improved consumption, is not enough to improve nutritional outcomes. Commercialization of farming can actually have negative effects for the poor [16]. In Ethiopia, some studies have found that livestock ownership led to increased income from the sale of animal products, enabling households to diversify their incomes [17]. However, Hoddinott et al. [13] found that this was mediated by market access; households with limited market access provided more milk to their children, whereas those who are able to access markets sold the milk.

Affordability High costs of nutrient dense foods, especially for those at greatest risk of poor nutrition, is a major challenge in Ethiopia [18–20]. Underdeveloped markets, poor transport linkages and weak infrastructure. Own production is an important way to increase household dietary diversity and improve nutritional intakes in rural areas.

A study looking at the consumer price index over the last ten years found that the relative price of nutritious foods in Ethiopia has increased substantially - especially for vitamin A rich foods (a real price increase of 80 percentage between 2007 and 2016) and other fruits and vegetables, which increased 40 percent during the same period, while foods that are linked to increasing rates of obesity (fats and sugars) have actually decreased in price, as have the relative costs of staple foods [21].

Consumption Major constraints related to nutritious food consumption in Ethiopia include low levels of awareness of nutritional issues, low purchasing power, the high price of nutritious food, and low supply of nutrient dense crops [22]. While many agricultural interventions have been successful in their ability to increase food production, this does not necessarily lead to improved nutrition, with nutritious crops often sold to purchase less nutritious, cheaper crops [23].

While Ethiopian policies have focused on promoting production of staple foods in order to increase food security, this has sometimes happened at the expense of increased production of more diversified foods [18]. While Ethiopia has seen an over 50 percent increase in agricultural production between 2011 and 2015, this has been driven by an increase in production of grains, roots and tubers, which account for a growing share of Ethiopia's food availability (86 percent of all energy produced in the country in 2015) [6]. Fruits and vegetables contribute less than 1 percent of the energy supply [6]. This is in part because the nutrition issues are not prioritised by the extension system, which is focused on cereal crop production to achieve food security [24], a focus which may actually be driving a decline in dietary diversity [19].

The BENEFIT partnership, which is introduced shortly (see 2.1), organized agricultural research for development (AR4D) interventions aimed mainly at increased availability and accessibility and only occasionally at increased dietary diversity, not changes in nutritional status (such as stunting or wasting). This is consistent with similar types of projects which focus on increased production diversity and increased knowledge promotion [25]. Malnutrition (stunting, wasting, underweight) is caused by multiple factors, including access to healthcare, sanitation and hygiene practices and childcare practices, nutritional awareness and cultural practices including gender norms and relations [26,27], which have not been the focus of the BENEFIT partnership. This focus on increasing dietary diversity to support improved nutritional status is also supported by findings that low levels of dietary diversity are linked to stunting and micronutrient deficiencies in the Ethiopian context [28].

1.2. Agricultural research for development projects: what role can they play in supporting nutrition sensitive agriculture

This paper explores the role of agricultural research for development projects in supporting improved nutrition, specifically increased consumption of more diverse diets for farming households in rural Ethiopia, and reflects on the policy implications of this research. Using data gathered from five projects of the BENEFIT Partnership presented in the next section implemented over five years (2016-2020) in four regions in Ethiopia; Oromia, Amhara, SNNPR, and Tigray. The main focus of the BENEFIT partnership was to support the Ethiopian efforts towards food security through the Agricultural Growth Program and the Productive Safety Net Program. However, despite the efforts of these programs, farmers still face a range of challenges including access to quality seed of improved varieties, fertilizers, and knowledge of other improved agricultural practices, as well as questions about how to practically implement nutrition sensitive policies [29]. This paper specifically looks at how the AR4D interventions contributed to an increase in availability, accessibility, affordability and utilization of more diverse agricultural products for improved dietary diversity and makes suggestions for how nutrition sensitive agricultural policies could incorporate these findings.

2. Context and conceptual framework

For the analysis of 5 years of project interventions that were designed to contribute to nutrition sensitive agriculture we used qualitative methods. Section 2.1 summarizes the 5 projects that together made up the BENEFIT partnership; in section 2.2 we describe the TANDI framework, a conceptual framework which conceptualizes pathways between agriculure and nutrition, that was used to assess the interventions, Table 1 indicates the specific pathways for the interventions and the data sources. Section 3 describes the contribution of the intervention to

Table 1
Nutrition Sensitive Interventions and targeted pathways.

Intervention	Targeted pathway	Examples	Data source
Seed portfolio diversification	1, 2 & 6	Participatory variety selection & crowdsourcing for selection of a diverse seed portfolio	[33–36]
		Seed production of pulses	[33–35,37,38]
		Seed potatoes	[33–35,37,38]
		Seedlings of papaya Maradol variety	[33–38]
		Vegetable seed system analysis	[36]
Home gardens	1 & (to a lesser extent) 2; 4 & 5 to be considered from a gender perspective	Introduction of home gardens with a mix of crops such as tomato, green leafy vegetables, carrots, fruits for home consumption and sales of surplus	[33–38]
		Integration of community-based nutrition including home and school gardening	[35,38]
Promotion of nutrient dense and biofortified crops	1	Quality protein maize (QPM)	[34,35,38]
		Orange-fleshed sweet potato (OFSP)	[33,35–38]
		Soybean: growing, cooking and processing focusing on removing anti-nutritional compounds	[33–35,37,38]
		Sweet lupine	
Introduction of rotational crops	1, 2 & 3	Soy and mung bean, sunflower as a rotational crop	[33–38]
		Multi stakeholder platform for improved marketing of pulses	[33–38]
Promotion of animal source foods	1, 2 & 6	Pullets, including both for households as well as small scale businesses (raising pullets)	[35,36,38]
		Youth groups producing eggs as a business	[35,36,38]
		Small scale ruminants (sheep and goats, both for household income and business)	[35,36,38]
Post-harvest preservation technologies	1 & 2	Technologies for food preservation using zero- energy evaporative cooling (pot-in-a-pot)	[36]
		Purdue Improved Crop Storage (PICS) bags	[33–38]
		Improving food safety	[33–37]
Labour saving technologies	4 & 6	Avocado harvester	[38]
		Enset scraper	[33,35–38]
		Fuel efficient stoves	[35,36,38]
		Maize sheller	[35,36,38]
		Animal drawn potato digger	[35,36,38]
		Treadle pump	[35]
		Water pully	[35]
		Water transport cart	[36]
Behavioural change communication	4, 5 & 6	Integration of community-based nutrition including nutrition education at village level	[33–38]
		Validation of intra-household dynamics study	[34–36]
		Nutrition education for farmers including food safety and hygiene messages	[34,35,38]
		Training on nutrition for agriculture and other extension workers	[34–36,38]
		Training on preparation of new agricultural crops	[33–38]

the TANDI framework pathways in detail.

2.1. Context

The Bilateral Ethiopian Netherlands Effort for Food Income & Trade (BENEFIT) partnership sought to (i) increase quantity and quality of sustainable agricultural production, (ii) improve markets and trade; and (iii) strengthen the enabling institutional environment for the agricultural sector including by mainstreaming gender and nutrition. The five projects, together comprising the BENEFIT partnership, were designed using an implicit conceptual framing of how specific agricultural interventions might impact nutritional outcomes. Each of the projects had their own specific focus and nutrition sensitive agricultural interventions, specifically:

- Integrated Seed Sector Development in Ethiopia (ISSD), which supported the development of a vibrant, pluralistic and market-oriented seed sector in the country. Nutrition activities under ISSD included diversifying the seed product portfolio in terms of the number of crops and varieties on offer (including, pulses, orange-fleshed sweet potato (OFSP), finger millet, sesame and linseed), supporting access to seeds for nutrient dense crops, for example by mapping vegetable seed producers and linking them to farmers, and behavioural change communication promoting crop rotation, and diversity of crops in both production and consumption.
- Capacity building for scaling up of evidence-based best practices in agricultural production (CASCAPE), which sought to improve agricultural productivity through promoting evidence-based best fit agricultural practices. Nutrition activities included home gardens, intercropping with legumes, and piloting and pre-scaling activities with high yielding papaya varieties.
- CASCAPE Nutrition and Gender (CANAG), a sub-project of CASCAPE sought to explore and pilot promising nutrition and gender sensitive technologies from the CASCAPE project. These included agricultural technologies such as home gardens, but also post-harvest technologies, labour saving technologies and validation of a tool to increase understanding of gender roles in intra-household decision making.
- The Ethiopian-Netherlands Trade Facility for Agribusiness (ENTAG) supported private sector development and trade in Ethiopia. This project did not work with primary producers but rather food processing companies. Commodity specific platforms also assisted the other projects by providing marketing opportunities for smallholder farmers. Nutrition work focused on food safety issues including improving food safety standards in poultry processing and reducing aflatoxin contamination and pesticide residues in pulses and spices to support companies in accessing export markets.
- The Sesame Business Network (SBN) supported stakeholders in developing competitive, sustainable and inclusive sesame value chains in Ethiopia. Working mainly in the Northwest of the country, the project supported planting home gardens and efforts to improve the diets of the large number of seasonal labourers working in sesame production as well as introducing rotation crops including pulses, soy, mung bean, and sunflower.
- Realising Sustainable Agricultural Livelihood Security in Ethiopia (REALISE) aimed to contribute to sustainable livelihoods through the introduction of improved farming practices, innovations and social

experiments to strengthen the current Productive Safety Net Program (PSNP) in Ethiopia. Because the project focused on some of the poorest households, nutrition was a key focus. Promoted technologies included biofortified crops (quality protein maize, OFSP), home gardens and production of animal source foods including poultry and dairy goats.

Working through partnerships with universities, agricultural research organizations, government at different levels, non-governmental organizations (NGOs), public enterprises, and private companies, ISSD, CASCAPE, CANAG, ENTAG, SBN, and REALISE each worked towards achieving change in their specific focus area [30]. The combined activities covered in total 233 districts, called *woredas* in Ethiopia, in the four regions, Amhara, Tigray, Oromia and the former Southern Nations Nationalities and Peoples Region (SNNPR) (Fig. 1), just over 800,000 farmers participated of whom 20 % were women. All projects applied a mixed-method approach of combining quantitative data with qualitative data based on interviews, focus groups discussions, preference assessments and documentation of stories of change. Data for this analysis have been drawn from detailed reports (see Table 1).

Fig. 1. Overview map of implementation *woredas* of the BENEFIT partnership (2016–2021).

2.2. Conceptual framework

The Nutrition Sensitive Agricultural Strategy of the Government of Ethiopia presents a conceptual framework for nutrition sensitive agriculture. It includes three pathways through which agriculture may influence nutritional outcomes, namely food production, agricultural income and women's empowerment [24]. The TANDI Framework [31, 32] is more expansive and includes six distinct pathways which is used as the conceptual framework for this paper's analysis.

1. Agriculture as a way for the household to produce food which they consume themselves.
2. Agriculture as a means of income which can be used by the household to purchase food.
3. Policies which impact agricultural production which leads to changes in prices and overall supply and demand factors.
4. Women's employment in agriculture and impacts on the childcare and child feeding practices.
5. Women's employment in agriculture and how it affects their own health and nutritional status.
6. Women's employment in agriculture, which can lead to increased control over resources and decision-making power in the household.

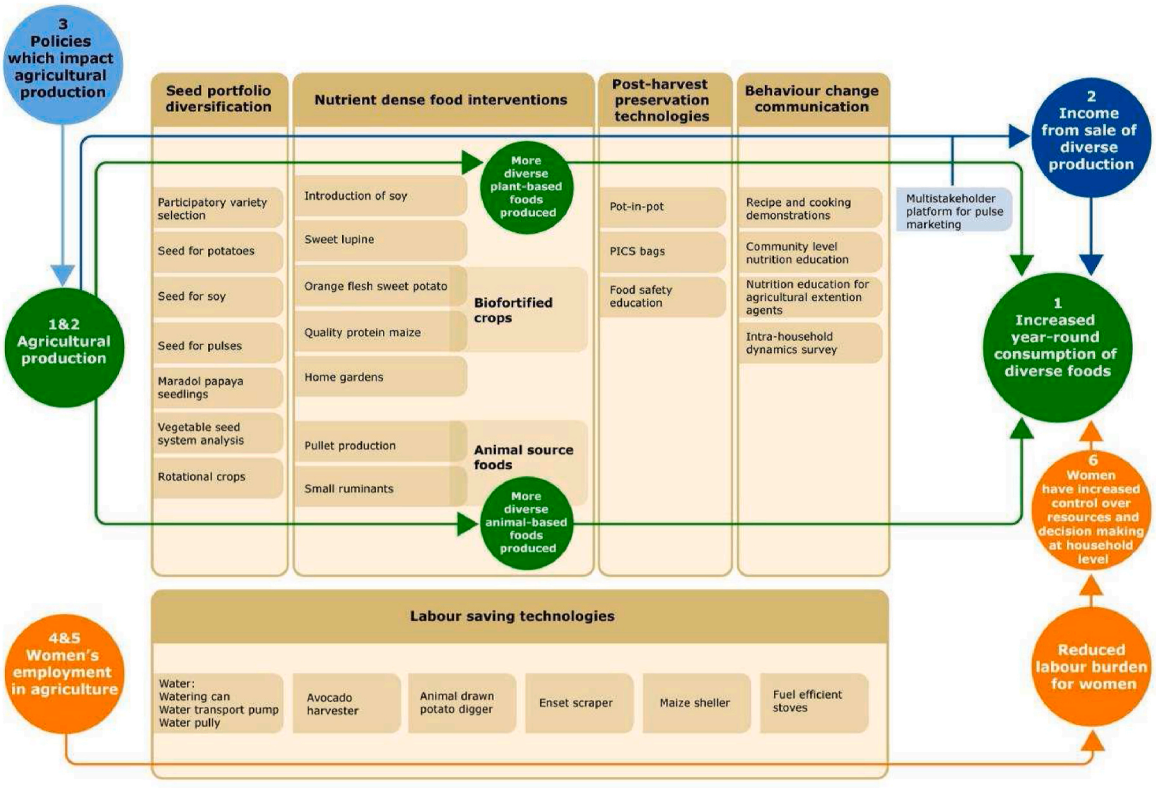

Fig. 2. Conceptual framework combining the specific nutrition sensitive interventions and the pathways towards improved nutrition. The numbers refer to the TANDI framework.

The nutrition sensitive interventions that were implemented and the targeted nutrition sensitive pathways are provided in Table 1 and the conceptual framework in Fig. 2.

The majority of project interventions, diversification of the seed portfolio, nutrient dense foods, post-harvest technologies and behavioural change communication focused on agricultural production and increased income, pathways 1 & 2 respectively. Both these pathways are greatly influenced by pathway 3, policies that influence agricultural production. All five projects also engaged in the policy space, with an ambition to translate research findings into improved agricultural policies. The interventions that addressed women's employment in agriculture, pathways 4 and 5, were mainly aimed at labour saving technologies or addressing intra-household dynamics. All interventions can potentially contribute to the sixth pathway where women have increased control over resources and decision making (Fig. 2).

3. Description of interventions and results

In this section the specific activities for each intervention, seed portfolio diversification, home gardens, promotion of nutrient dense and biofortified crops, introduction of rotational crops, promotion of animal source foods, post-harvest preservation technologies, labour-saving technologies, and behavioural change communication, are described. This is followed by quantitative and qualitative evidence illustrating how the interventions have or have not contributed to improved dietary diversity.

3.1. Seed portfolio diversification

A variety of interventions to diversify the number of crops and varieties in the collective portfolio of farmers, seed producer cooperatives, private seed producers and companies, and public seed enterprises producing and distributing seed in informal, intermediate (or integrated) and formal seed systems were conducted. Among these were participatory variety selection (PVS) at farmer training centres and on-farm variety testing and selection through the tricot (triadic comparison of technologies) experimental design [38,39], a form of citizen science which the projects' called crowdsourcing [39]. It was assumed that increased availability of quality seed of a diverse range of crops and varieties will lead, in turn, to increased diversity in crop production and food consumption.

Quality seed of 392 varieties of 35 different crops was multiplied through support to different types of seed producers [38]. This marked a 17.6 percentage increase in the number of crops, and a 22.5 percent increase in the number of varieties, compared to the previous year. 169 seed producer cooperatives, sole proprietors and private limited companies were supported to produce and market quality seed of 202 varieties of 38 different crops, which could support up to 4.2 million farming households to access quality seeds.[1] In the PSNP areas the crop variety portfolio of participating smallholder farmers increased 160 percent, from 68 varieties to 177 varieties.

Another intervention was the promotion of seed production of different pulses that are rich in affordable protein and minerals as well as excellent for soil health by including these in crop rotation practice. Promoted pulses included chickpea, faba bean, field pea, haricot/common bean, lentil, and soybean. Nutrient dense tubers, OFSP, and cereals, finger millet (rich in minerals, esp. calcium), were also promoted.

What does this mean for nutrition? The nutritional values of pulses, oilseeds, quality protein maize, finger millet, OFSP and some fruits are evident. Comparing panel data collected during end- (n = 1612) and baseline (n = 1636) seed availability and use surveys revealed that quality seed is now more easily obtained in the intervention areas than before (p, 0.05) [34]. Reports that quality seed is difficult to obtain dropped 10 percentage points from 2016 to 2020 (p, 0.01), and the share of seed being sourced from intermediate (or integrated) and formal seed systems has increased significantly for all major crop types, and intervention communities are using 23 percent more seed. Farmers are reportedly harvesting more produce, which one third of respondents attribute to the use of quality seed (p, 0.01). Surveys show improvements in women's influence over decision making on what to sow, including a drop in frequency of husbands taking all decisions unilaterally (13 percentage points), and an increase in husband and wife deciding what to plant together (16 percentage points, p, 0.01).

3.2. Home gardens

Home gardens are perhaps the most well-known example of nutrition sensitive agriculture. Home gardens, or the small-scale year-round production of fruits, vegetables, and herbs, usually for consumption by the family, has been a common practice for thousands of years, including in Ethiopia [39]. A small surplus may also be sold, increasing access to fruits and vegetables for other community members [40]. The Ethiopian government's National Nutrition Program and Nutrition Agricultural Strategies set targets for adoption of home gardens in Ethiopia; aiming for 40 percent of all rural households and 25 percent of urban households to have a home garden by 2020 [29]. The National Nutrition Sensitive Agrifood Systems strategy builds on the previous strategies. The mix of crops promoted in home gardens in BENEFIT were purposefully selected to include those which are particularly nutrient dense and are commonly consumed. These included carrot, beetroot, Swiss chard, tomatoes, and Ethiopian kale, among others.

Participants across a range of geographies in four regions of Ethiopia, were supported in setting up home gardens. While the type of support was not uniform across BENEFIT projects, there were some commonalities. Participants were supported with agricultural inputs as well as practical training which was usually delivered to emnployees of the government extention system including subject matter specialists, agriculture development agents and health extension workers, who in turn provided training to farmers.

The majority of the AR4D interventions in BENEFIT did not have a specific nutrition focus, and pre- and post-intervention dietary diversity was not always measured. In the CANAG project, which had a more explicit nutrition focus, data on dietary diversity of the participants was collected at baseline and endline. In this project, home garden interventions, combined with nutrition education, were able to increase the dietary diversity score (DDS) for women of reproductive age, but not of their children [40]. The mean baseline DDS for women of reproductive age was 3.64 (SD = 1.37) and endline was 4.05 (SD = 1.57) with an average improvement of 0.4 food groups (SD = 2.1, $P < 0.001$). However, for children between 6 and 23 months, the mean DDS comparing baseline and endline did not increase. At baseline the means DDS was 3.17 (SD = 1.23), the endline was 3.23, (SD = 1.54, P = 0.59).

Where chronically food insecure households were targeted, household level food insecurity was measured by food gap months. Four groups were compared, those that participated in the REALISE intervenion, either non-PNSP household or PNSP household, and those that did not participate in the REALISE intervention, either non-PSNP households or PNSP households. Non-PNSP households that participated in project interventions experienced only 2.8 food gap months as compared with the control group of non-PNSP households who did not participate who experienced 3.1 food gap months. The impact for PSNP households specifically (i.e., direct beneficiaries of PSNP) who participated in REALISE interventions had 3.1 food gaps months compared to 3.6 months for those who did not participate in the project (Fig. 3). There was also an improvement in dietary diversity between the the households who did not participate in REALISE and those who did although assets measured as tropical livestock units (TLU). This difference was only significant for PSNP households.

[1] Estimate based on average landholding and sowing rates.

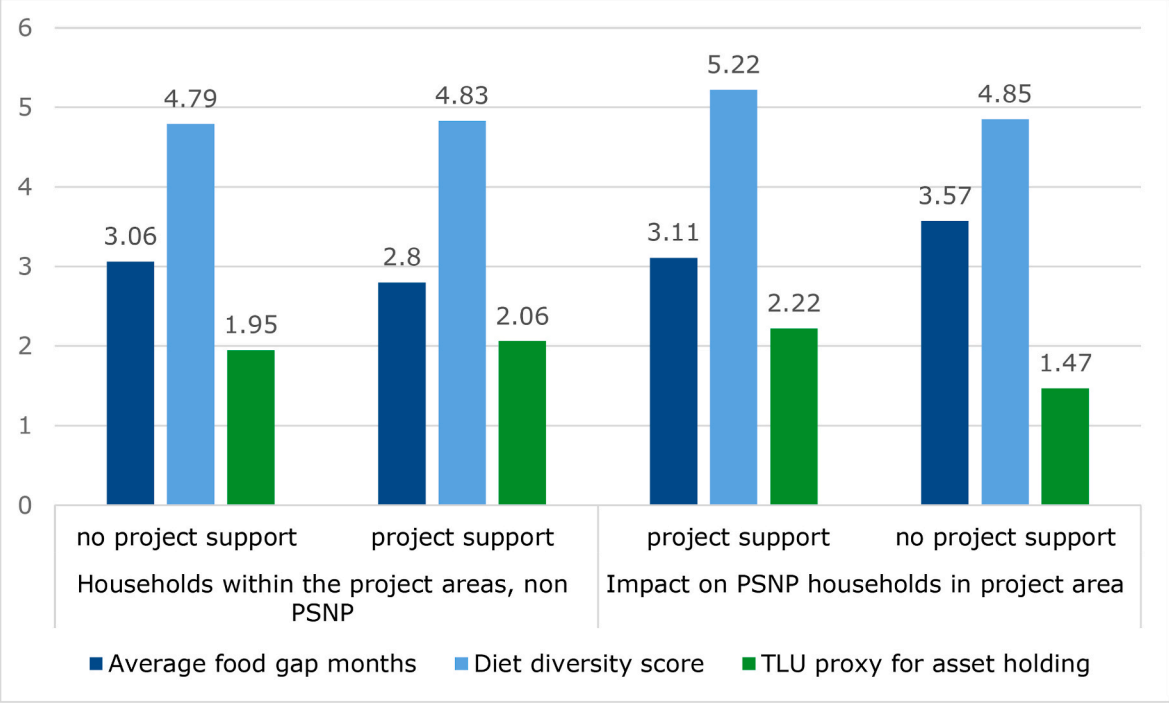

Fig. 3. Comparison of food gap months (in no of months), dietary diversity (in no of food groups) and tropical livestock units (in TLU – used as a proxy for assets) between non-PSNP households participating in project interventions (2) non- PSNP households not participating (1), PSNP households participating in project interventions (3), and PSNP households not participating in project interventions (4).

Qualitative data, collected using the Stories of Change methodology, found that households appreciated home gardens and mentioned that their own and their family's health had improved as a result of increased consumption of both fruit and vegetables. Gender is a key element to consider, given the large role that women play in providing labour for home gardens. One study found that when home gardens became profitable, they were often taken over by the men in the household (de Roo, 2017 personal communication). The CANAG project, which had an explicit gender focus, found that both women and men work in the home garden, with men supplying labour for larger tasks like preparing the land and women providing ongoing support such as weeding and watering. A survey of over 100 CANAG home garden participants found that the vast majority (>90 percentage) of women and men would continue the home gardens in the rainy season. However, participants in Tigray are less likely to continue with home gardens in the dry season, mentioning water access as a key limiting factor.

3.3. Promotion of nutrient dense and biofortified crops

Quality protein maize (QPM) has been bred to contain high levels of several amino acids essential for humans. Studies in Ethiopia have found that consumption of QPM has contributed to effectively prevent, and in some cases reverse growth faltering in young children [41]. Acceptability studies have also found that both women and children were more likely to prefer quality protein maize compared to conventional maize when evaluating factors such as taste and aroma [42]. QPM was introduced as part of the participatory variety selection activities.

Orange-Fleshed Sweet Potato Vitamin A deficiency is linked to a poor immune function leading to increased susceptibility to a range of diseases, as well as vision impairment and, in cases of extreme deficiency, blindness. OFSPs, which contain high levels of bio-available vitamin A, are an affordable way to deliver vitamin A to potentially deficient populations [43]. OFSP is a key food security crop as it can withstand drought, does not require large amounts of land and is relatively cheap to produce. New varieties, such as Adu, which are high in vitamin A, early maturing and drought tolerant were developed and released by Haramaya University, but adoption and distribution has been limited to high potential areas.

Qualitative data collected from farmers in the intervention villages found that the yield of the new variety Adu is 3 times higher than the traditional sweet potato, which, coupled with the early maturing time and the drought resistance, has contributed to the decrease in months of food insecurity (see Fig. 3). Haramaya University has continued to support the dissemination of orange-flesh sweet potatoes in their work following the end of the project, suggesting ongoing interest in the crop.

Quick maturing and high yielding varieties of papaya Ethiopians have very low levels of fruit consumption, with baseline data finding that fruit is only consumed by one percent of households. Maradol papaya, a quick maturing variety which can provide fruit within a year and is very high in a number of key micronutrients including vitamin A, E, C as well as a number of minerals [44] was promoted by the REALISE project in both the high potential as well as in the PSNP areas.

Seedlings of Maradol papaya were distributed in all intervention areas participating in the REALISE project. Qualitative data collection found that the farmers, especially female farmers, appreciated the minimal labour that the papaya required as well as the high yield. Papaya was both consumed by the household, as well as sold to allow for the purchase of food and to pay for other household costs such as school fees. The production of Maradol seedlings became a lucrative enterprise for some households.

3.4. Intercropping and rotational crops

Intercropping is often used as a way to intensify crop production as well as increase soil fertility. Soybean was promoted both as a way to increase soil fertility as well as to increase access to protein. In the sesame producing areas, mung beans were promoted as a rotational crop to increase soil fertility as well as to improve diets for labourers working in the sesame sector.

CASCAPE introduced soybeans, which were previously not

commonly grown, as a rotational crop in Southwest Oromia in both research (higher levels of technical support) and non-research (lower levels of technical support) *woredas*. In research *woredas*, recipe demonstration was also included. In those areas in which consumption was stimulated through recipe development, only 33 percent of the soybeans were sold, compared to almost half (47 percent) in the areas where consumption was not stimulated. However, a number of constraints and challenges remain with regards to the soybean value chain including lack of market and incentive for farmers, which may limit further uptake. The ENTAG project supported development of the soybean value chain by establishing a platform to support trade, however this is still in its infancy.

Because AR4D efforts focussed on productivity, there was often a bias towards cash crops. On-farm trials identified mung bean as the best rotational crop for increasing sesame productivity. While consumption and nutrition benefits were a secondary concern of SBN which mainly focussed on sesame, if participants were not interested or willing to consume a crop, they would also be less interested in producing it. Supporting farmers as well as labourers, to use the mung bean, a new crop, in the production of traditional dishes, improved willingness to adopt the technology. More research is needed to understand the impact this may have had on the diets of the labourers, who have a very limited dietary diversity.

3.5. Promotion of animal source foods

Animal source foods can be an important source of proteins, fats and key micronutrients that are often deficient in diets based many on cereals, such as those in rural Ethiopia [45].

Dairy goats Goats have been found to be the preferred livestock species by smallholders in Ethiopia as they can provide the family with a range of benefits, including milk, meat, and manure, as well as the potential to be sold for income if necessary [46]. Dairy goats were distributed, together with training on goat management, to increase household access to milk. The goats provided milk for an average of 3.5 months in a year. Goats were less affected by disease as compared to chickens, also promoted in the project, and 60 percent of participants had access to veterinary services and the vast majority (80 percent) could easily access feed. However, the labour burden also seemed to be significant, with only 60 percent of women reporting they would continue with the goats, and even fewer husbands (30 percentage) supporting continuing with goat rearing, especially in the dry season, a finding which warrants additional research. Qualitative data collected from PSNP areas suggest that while the dairy goats are highly valued, they require large amounts of food, which can be labour intensive to collect. Additionally, goat milk is not commonly consumed in Ethiopia, which may also have implications for the acceptability of dairy goats.

Sheep In North Wollo, female PSNP beneficiaries were supported to establish businesses to raise sheep. Qualitative data indicates that women were able to establish successful businesses with the support provided through the project, and that the increased income also contributed to improved dietary intakes of their household.

Small scale poultry production Eggs are commonly promoted in resource poor settings, as they are often the most affordable way of introducing animal source foods into the diets and contain high levels of protein, fatty acids, essential nutrients including vitamins A and B12 [47]. However, the introduction of new more productive chicken breeds needs to be done within the overall context of adequate support systems. Initially, 3 day old chicks of an improved breed were distributed to farmers. However, the chickens suffered from high mortality due to disease and a shortage of adequate food. Learning from this experience, 3 month old pullets obtained from youth groups were distributed to farming households in Bahir Dar and Mekelle intervention areas. A survey of 20 participating households found that approximately 50 percent of the chickens suffered from disease. In Bahir Dar 70 percent of households still reported that feed was challenging to obtain, and only half of participants indicated a willingness to continue with the pullets.

Youth were also supported to establish egg production businesses, through training and initial capital. Qualitative data using stories of change methodology found business owners were able to generate adequate incomes, and that the business activities were not too time intensive and actually allowed women more time to carry out other domestic activities at home.

3.6. Post-harvest preservation technologies

While the majority of interventions in the BENEFIT partnership focused on production related technologies, the CANAG project, which had a specific gender and nutrition focus, also introduced post-harvest technologies to allow households to store nutrient dense crops for longer, aiming to increase dietary diversity year round. The project focused on three technologies viewed by experts as most appropriate for the context, two zero-energy cooling technologies (pot-in-pot and basket-in-basket which use evaporation to keep products cool in the absence of refrigeration) as well as the Purdue Improved Crop Storage (PICS) hermetic bag, which prevents pest infestations in stored crops.

The pot-in-pot was mostly used to increase the shelf life of vegetables (Ethiopian kale, Swiss chard, carrots, cabbage, beetroot and tomatoes) and occasionally fruit (avocado, papaya, mango). Approximately half of respondents reported that perceived shelf-life of vegetables stored in the pot-in-pot doubled, with a quarter reporting that the shelf life more than doubled. The vast majority (92 percentage) reported that they would choose to purchase the technology themselves. However, approximately half of respondents reported that the technology is not easily available for purchase.

Food safety is an important issue in relation to post harvest handling. A commodity specific platform for pulses, which brought together both exporters and domestic processors, indicated a policy gap around maximum residual limits for both aflatoxins and pesticides, leading to many foreign countries to reject Ethiopian exports. Two critical challenges were identified, one was related to the absence of policies clearly defining aflatoxin limits, and the other was limitations in testing capacity. To address these bottlenecks, the creation of the Ethiopian Pulse Council was supported to enhance investment in quality assurance, address critical bottlenecks, foster value addition and processing by supporting technological innovations and improve market competitiveness through quality assurance, market orientation, branding, and promotion [48].

3.7. Labour saving technologies

A 24 hour mapping of men and women's time use, carried out as part of a participatory rural appraisal, showed that women, because they have both domestic tasks including childcare, cleaning and food preparation, as well as on-farm tasks, work for an average of 1-2 hours more a week than men, and have less free time. Because of the domestic work responsibilities of women, introducing new farm activities may take away time from care activities, negatively affecting the nutrition intake of themselves (additional work) and their children (less time to breastfeed or prepare healthy foods). The nature of women's activities means that women's energy use and expenditure did not vary across agricultural seasons, whereas men's does, reflecting a difference in types of agricultural activities [50]. Introducing labour saving technologies specifically aimed at women can potentially lessen their work burden [49].

Survey data found that an avocado harvester, and fuel-efficient stoves were the highest ranked technologies introduced by the CANAG project, especially in terms of ease of use, time savings and improvement on the previous technology. Two of the labour-saving technologies, maize sheller and potato digger received poor ratings from the community related to frequency of use (65 percent of participants reported never or seldom using the maize sheller and 70 percentage never or

seldom using the potato digger).

3.8. Behavioural change communications

There is evidence from a range of nutrition sensitive programs that they are much more effective if they incorporate behavioural change communication around the importance of nutrition and consumption of nutrient dense crops, in addition to supporting increased agricultural production [51]. Recipe development and product tasting for a range of newly introduced foods were at times, but not consistently, included in BENEFIT interventions. In CANAG the project worked in schools and communities to support nutrition education promoting the consumption of diversified diets, however no specific data regarding changes in consumption as a result of these interventions, was collected.

4. Discussion

While not explicitly focused on nutrition sensitive agriculture, projects in the BENEFIT program supported all six pathways through which agriculture is thought to influence nutritional outcomes. The following section considers how agricultural research for development projects can contribute to these pathways, then reflects on the policy implications.

4.1. Contribution of the interventions to nutritional outcomes

Most of the nutrition sensitive interventions promoted by the project and described above indicate that pathways 1 and 2 are highly linked, and that most households consume some of what is produced and sell the surplus for additional income. Increased awareness raising activities, for example promoting consumption and demonstration of soybeans, seems to shift the balance slightly towards consumption rather than sale. Livestock (chickens and goats) are particularly valued for income generation, however especially goats are labour intensive and require high inputs. Generating some income from nutrition sensitive agricultural projects is also likely to increase sustainability, as farmers will be able to re-invest the following season. However, behavioural change communication, in addition to increases in income, is necessary to increase dietary diversity.

Home gardens supported in the program were shown to increase the dietary diversity of women, but not of children. Challenges related to the sustainability of home gardens include water access, as lack of water was a key factor for families to make decisions on continuing home gardens, a finding which is supported in other studies [52,53]. Home gardens do show promise as a way to increase dietary diversity, however support systems (seed supply, small scale irrigation) should be supported by involving stakeholders beyond the government agricultural system, for example the private sector.

Promotion of specific nutrient dense crops such as OFSP seems to be promising as a way of increasing household food security, with an additional benefit of high levels of vitamin A. Adaptability to a changing climate also seems to be a key factor linked to increased uptake. New varieties with multiple favourable characteristics (e.g. drought tolerance, high yield, early maturing) should be further developed, piloted and scaled within the agricultural research system.

In the sesame production area, increased income leads to general improvement of living conditions, including housing, health, education and transport [54]. Increased income does not necessarily translate to increased dietary diversity. Access to affordable credit, training in financial literacy and saving practices were found to be very important for households to secure and manage their income, which is necessary but not sufficient to increase household dietary diversity.

Ethiopia currently does not produce sufficient quantities of diverse foods to enable adequate consumption at the population level. ISSD interventions supported increased availability and diversity of seeds for staple crops, however access to vegetable seed remains a challenge. Ethiopia produces only a few types of vegetables (mainly onions and chilli), for which it is reliant upon imported seed, with the Netherlands meeting approximately 80 percent of that demand [55]. Farmers participating in CANAG reported having to travel 2–5 h round trip to obtain vegetable seeds. Access to quality vegetable seed is a key policy area identified by the project, as well as others working on home gardening in Ethiopia. A number of solutions were put forward to increase access to vegetable seeds including forming farmer cooperatives to organize bulk purchases, promotion and sale of smaller seed packages as more immediate solutions, with longer term ambitions to increase domestic capacity to produce vegetable seeds, and the numbers of registered varieties.

An intra-household dynamics study supported communities to identify key areas where new gender roles and responsibilities could support the nutritional status of the family. Male community members recognized that they have an important personal contribution to make to their family's nutrition and could be more actively targeted in nutrition sensitive agricultural projects. Women who participated in the intra-household study want to see husbands providing increased support for household tasks. However, most male respondents believed that despite the heavy workload that women carry, household tasks are their responsibility [56]. Agricultural research projects can play a role in stimulating reflection on women's role in providing both agricultural and domestic labour, and care should be taken to ensure that new technologies do not create too high a burden for women.

A range of labour-saving technologies were introduced as a way of reducing women's labour burden. While perhaps a promising approach, many of these technologies proved difficult to purchase as many are still produced by the agricultural research system and not widely manufactured. Delays in procurement meant that they were not always available for the correct agricultural season. Local knowledge to repair the technology was often absent. Some technologies were challenging to use, highlighting the need for more community testing of such technologies. Community access to, and ability to repair such technologies needs further support and additional actors, for example the private sector, should be engaged for the identification of such technologies.

Studies looking at the impact of the food price shocks of 2008 found that women are often "shock absorbers" reducing their consumption to allow others in the household to consume more. They also found female headed households are more likely to be impacted by increases in food prices [57].

A post-intervention study found that the package of nutrition sensitive agriculture (home gardens and/or animal production) combined with messaging on behavioural change, and in some areas work to address gender dynamics within the household, was able to increase women's dietary diversity. Additionally, the majority of women did not indicate that the innovations such as home gardens took too much of their time, relative to the benefits, especially in the rainy season. While this suggests that agricultural innovations to increase the supply of diverse foods can be implemented in a way that does not negatively impact women's own health, this needs to be done in a considered way, otherwise they may overburden women.

While the BENEFIT partnership did engage with intra-household dynamics and considered issues around control of resources within the household and household level decision making, this was a challenging area for an agricultural project to enter. Some researchers felt that an agricultural project should not work at the level of intra-household decision making, which some feared might lead to conflict within the household. Because the project was mainly run by those with an agronomic background, it was at times challenging to find individuals to facilitate such work.

An intra-household dynamic study found that for household finances, men reported that they routinely made household decisions on spending, although some cited that their wives could spend money, and that they often consulted their wives on major financial decisions, a finding that is echoed by women. However, women generally make the

decisions about what foods to buy at the market. Emphasis on financial literacy training encouraged intra-household discussions about the use of the household income. Findings suggest that AR4D projects can and should support the increased role of women in decision making around issues of both production and consumption.

4.2. From nutrition sensitive agriculture to nutrition sensitive food systems

Over the five years that the BENEFIT partnership was implemented, the narrative around healthier diets has shifted from thinking about nutrition sensitive agriculture to considering food systems more broadly, focusing not only production and consumption but links between the two, and the overall system through which people obtain food. This is supported by the following policy implications, all of which highlight the need for a more systems based understanding.

Support systems to enable nutrition sensitive agriculture should be strengthened. While a number of the nutrition sensitive interventions show promise in increasing access to diverse foods, more is needed to develop adequate support systems including access to agricultural inputs as well as credit and financial services. Without these services, interventions aimed at stimulating increased supply of nutritious foods will remain unsustainable. Caution should be exercised when introducing animal source foods, especially new breeds, to ensure that adequate support systems are available especially veterinary services and feed.

As has been found in other studies, adding in a project element to stimulate consumption of new crops or the importance of diverse foods, is necessary to translate increased production into increased dietary diversity. This seems to be particularly true when introducing a crop that is new e.g. soybean. However, until recently it has not been the role of agricultural extension agents to promote increased consumption. With the new training on nutrition sensitive agriculture introduced by the Ministry of Agriculture in Ethiopia, this is changing, but more could be done to better integrate agriculture and nutrition messaging, including supporting agricultural extension workers to feel more confident in promoting not only improved production practices but also increased consumption of nutritious foods.

Allen and De Brauw [58] caution that shifting the focus of the food system to be about delivering healthy diets may cause tensions or trade-offs with other food system outcomes, for example environmental or economic outcomes. The findings from the BENEFIT program suggest that it is possible to find solutions that support both nutrition and other food systems outcomes. Nutrition sensitive crops, for example biofortified crops, are more likely to be adopted if they are both nutrition sensitive and include other desirable characteristics like drought tolerance. Legume intercropping, promoted by BENEFIT for soil fertility, also has nutrition benefits.

While some labour-saving technologies currently available through the agricultural extension system show promise, more is needed to produce and market these at scale. It might be necessary to look beyond the government agricultural system to identify other promising labour-saving technologies and increase linkages with the private sector to improve access to promising new labour-saving technologies. Work on labour saving technologies should also include broader work in intra-household decision making and decisions around women's time use.

Finally, nutrition sensitive interventions in the context of agricultural research for development projects, should not be considered in isolation; rather as a package, as integrated approaches are needed. This package should include technologies to improve production and availability of nutritious foods while also looking at opportunities to improve the food environment, stimulate demand for nutritious foods, and support other food systems stakeholders including producers, value adders, consumers, and enablers.

5. Conclusion

Evidence from a 5-year portfolio of projects implemented to support the Ethiopian government to further develop the agri-food system has found that there is scope for agricultural research for development projects to work specifically on increasing access to and consumption of nutritious foods, but that this needs to be an explicit objective, and it cannot be assumed that improved production will lead to increased consumption of nutritious foods.

5.1. Remaining questions

- How, when and under what conditions can market access increase consumption of diversified diets? Understanding how increased market access can support improved incomes and how this can be translated into increased dietary diversity requires further research.
- While the need to stimulate both production and consumption is well documented, questions about how to best increase demand for, and consumption of new crops, is still not well known. Are activities like recipe development and demonstration of new foods actually able to stimulate change in diets? What is necessary to translate this into long-term changes in dietary patterns?
- There is still a significant gap in terms of domestic production of fruit and vegetables in Ethiopia. How can agricultural research for development projects support in reducing this gap?
- What role can financial literacy training and linkages to appropriate financial products promote nutrition sensitive agriculture?

The Government of Ethiopia has made significant progress in supporting more nutrition sensitive agricultural policies. This could be further strengthened by providing a package of integrated approaches which consider how both production and consumption of more diverse diets can be stimulated, including engaging with a broader range of stakeholders and actors to create a nutrition sensitive food system in Ethiopia.

CRediT authorship contribution statement

Katherine Pittore: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Legesse Abate:** Validation, Supervision, Investigation, Formal analysis. **Dawit Alemu:** Supervision, Resources. **Gareth Borman:** Writing – original draft, Formal analysis, Data curation. **Eyasu Elias:** Supervision. **Amleset Haile:** Supervision, Project administration, Conceptualization. **Desalegn Haileyesus:** Project administration, Data curation. **Jennie van der Kolk:** Project administration. **Irene Koomen:** Writing – review & editing, Writing – original draft, Supervision, Resources, Conceptualization. **Ted Schrader:** Resources, Project administration, Funding acquisition. **Eric Smaling:** Supervision. **Herman Snel:** Writing – original draft, Methodology, Data curation, Conceptualization. **Akalu Teshome:** Writing – review & editing, Supervision, Project administration. **Tewodros Tefera:** Resources, Project administration, Funding acquisition.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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