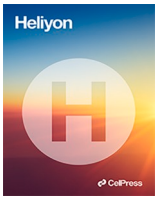
Heliyon 10 (2024) e28213

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Pathways and policy options for food and nutrition gaps in arid agricultural farming systems in the Tigray Region, north Ethiopia

Afeworki Hagos Mesfin [a,*], Kidane Giday Gebremedhin [b], Tewodros Tefera [c], Mulugeta Diro Chimsa [d], Remko Vonk [e]

[a] *BENEFIT-REALISE Socio-economics researcher, College of Dry Land Agriculture and Natural Resources, Mekelle University, P.O.Box: 231, Mekelle, Ethiopia*
[b] *BENEFIT-REALISE Programme Regional Manager, College of Dry Land Agriculture and Natural Resources, Mekelle University, Ethiopia*
[c] *BBENEFIT-REALISE Programme National Manager, BEFEFIT Partnership Office, Besrate Gabriel SAN Building 2nd Floor, Addis Ababa, Ethiopia*
[d] *BENEFIT-REALISE Programme National Deputy Manager, BEFEFIT Partnership Office, Besrate Gabriel SAN Building 2nd Floor, Addis Ababa, Ethiopia*
[e] *RemkoVonk, BENEFIT-REALISE Programme Coordinator, Wageningen University and Research (WUR), Netherlands*

A B S T R A C T

Food and nutrition security is a major global challenge especially indeveloping countries.Agriculture is main means of livelihoods and hunger is drastically increasing from time to time especially due to effects of climate change, conflict and other manmade and natural calamities in these countries. Similarly, the Tigray Region is one of the Ethiopia's most food and nutrition insecure regions with agriculture serving as the main source of income and employment. This study was therefore conducted to fill the gap in understanding the socioeconomic situation, bio-physical environment, institutional setting and policy landscape by analysing the existing circumstances in Tigray Region. This research employed quantitative data sets collected from 300 randomely selected Productive Saftey Net Program (PSNP) beneficiarieries and Non-PSNP households using probability proportional to size. The Household Dietary Diversity Score (HDDS) used as a proxy measure to nutrition security as our data is 24 h recall and food gap months as proxy to food security. Besides, Principal Component Analysis (PCA) method is used to construct household asset index. The results of the study revealed that there are clear and significant differences of the PSNP and Non-PSNP households, and gender in land holding ($p<0.01\%$), asset ownership($p<0.01\%$), food gap months($p<0.01\%$), dietary diversity($p<0.01\%$), exposure to hazards and risks, copping strategies, yield, access to agricultural extension services, access to improved varieties (varietal diversification). The male headed households, and Non-PSNP households are better off than the female headed and PSNP households' counterparts. Thus, provision of practical training, conducting farmer's participatory research, field days, promoting and creating access to farmers' preferred high yielding improved varieties and management practices available in the research and extension consortium, support in research and development that develops and disseminate appropriate technologies to help farmers to lower their food gap months is highly important. In addition, sustainable intensification, off-farm employment alternatives, and engaging in agribusiness activities that create resilient livelihood options to those resource poor farm households, strengthening the formal and informal seed system would help to reduce food gap months, improve HDDS, build resilience of the food and nutrition insecure households. Therefore, customized extension services and packages are important for addressing the food and nutrition security gaps by setting goal, outcome and output indicators for future interventions in the research and development arena in filling food gap months, dietary diversity and household asset building through collaboration among relevant stakeholders in the food system.

* Corresponding author.
E-mail addresses: ma8280@gmail.com (A.H. Mesfin), kidanegg@gmail.com (K.G. Gebremedhin), Amide.tewodros@gmail.com (T. Tefera), md.chimsa@yahoo.com (M.D. Chimsa), remko.vonk@wur.nl (R. Vonk).

https://doi.org/10.1016/j.heliyon.2024.e28213
Received 16 November 2022; Received in revised form 25 February 2024; Accepted 13 March 2024
Available online 26 March 2024

1. Introduction

Food and nutrition security have remained a major global challenge and agenda. The levels of food and nutrition insecurity have drastically increased. For example, one in every ten people is undernourished while one in every four is overweight; almost half the world's population cannot afford a healthy diet [1]. Food insecurity affects about 2.3 billion people worldwide (11.7%) (WHO, 2022).[1] These occur when the family members lack adequate physical, social and economic access to sufficient, safe and nutritious food to meet the dietary needs and their preferences for an active and healthy life [2,3][64–66,69]. In fact, food security and nutrition security are interlinked concepts. For this reason, new concepts have developed that emphasize the role of nutrition in health and "the coexistence of food insecurity and diet-related diseases and dis parities [67]. Nutrition security is closely related to, yet distinct from, food security and nutrition occurs when an individual has access to both an adequate quantity and quality of food to promote health across the life span and makes dietary choices that promote health and long-term well- being [68]. Different factors have attributed to food and nutrition insecurity including but not limited to heatwaves, floods, droughts and wars. Other factors like the incident of COVID-19 pandemic and armed conflicts raised the number of hunger people by 13% in 2020 [4]. Food insecurity is a major cause of all forms of malnutrition, including poor quality, insufficient quantity, and diet stability [3] (see Fig. 1).

Cognizant of the widespread problems and challenges that the world faces, the United Nations has come out with 17 Sustainable Development Goals (SDGs) for collective action in an effort to curb the root causes of under-development. SDGs, SDG 1 (No poverty); SDG 2 (Zero hunger); SDG 3 (Good health and well-being); SDG 5 (gender equality); SDG 6 (Clean water and sanitation); and SDG 12 (Responsible consumption and production) are all in some way related to food and nutrition security, which is the main thesis of this paper. For example, the United Nations' Zero Hunger (SDG 2) goal is to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture." The development goal also reveals that the number of people suffering from hunger has increased since 2014, particularly in Sub-Saharan Africa (SSA), where Ethiopia is located. Thus, about 795 million people worldwide (with 780 million are living in developing regions) do not yet have access to sufficient quantity and quality of food [6]. Food insecurity remains a a persistent global problem. Hunger and malnutrition continue to rise around the world unless immediate and long-term solutions are taken [7–10]. The percentage of undernourishment remains the highest among developing regions [11,12,13].The prevalence of hunger has increased from 20.7% in 2014 to 23.2% in 2017, indicating that an economic slowdown and adverse weather conditions are among the major drivers of the rising trends in hunger in Ethiopia [14].

Food and nutrition insecurity, a common feature of the developing world, has long been a development challenge in Ethiopia, and particularly in the Tigray Region. Thus, households are dependent on food aid programs (Productive Safety Net Programme) [15]. Thus, empirical evidences showed that the manifestation and nature of food insecurity and nutrition insecurity are sever ([15], [16], [17–23]]. The rate of low nutritional status of biological mothers and children, maternal and child mortality, stunting, wasting, food insecurity, hunger and under nutrition has remained consistent even in surplus-producing areas [19,24]. This implies that food insecurity is prevalent throughout Ethiopia, particularly in the Tigray Region.

Food and nutrition security have been remained as a major development challenge for generations in Tigray National Regional State for a foreseeable future. For this reason, most of the households are dependent on food aid resources like Productive Safety Net Programme (PSNP). The major reasons attributed to the prevailing food insecurity include climate variability, unreliable rainfall patterns, droughts, floods, unpredictable extreme temperature, aberrant weather and pervasive production risks [25–29]. This resulted in low yield and production.

Tigray is one of Ethiopia's most affected regions by recurrent drought and food security problems, which have forced many people to live in chronic hunger with a low average energy supply [30,31]. Land degradation, climate-induced recurrent drought and extreme weather variability have all had a significant impact on the region [[32,33]. Environmental degradation, irregular rainfall, high population pressure, recurring drought cycles, a lack of diversification in economic activities, and institutional factors all contribute to low level of food security [31,34].

The Government of Ethiopia has set explicit strategies like the National Nutrition Program and the Nutrition Sensitive Agriculture Strategy to promote nutrition. For example, Nutrition-sensitive agriculture is a food-based approach to agricultural development that prioritizes nutritionally rich foods, dietary diversity, and food fortification at the heart of overcoming malnutrition and micronutrient deficiencies. The overall objective of nutrition-sensitive agriculture is to improve the food system's ability to produce good nutritional outcomes [35].

Despite the fact that food and nutrition security are inextricbly linked, previous studies attempted to separate the depth and scope of food and nutrition insecurity in Ethiopia and Tigray Region. For example, Simone *et al.* [36] had investigated the role of access to improved seeds and agricultural technologies in rural development. Other studies have also focused on the changes in rainfall, temperature and weather variability and livelihoods [37,38] availability and to some extent the access of food and the productivity of farm households [26] and household capacities, vulnerabilities and food insecurity [39]. Further studies on food security and policy was conducted in Tigray [31,40]; and impacts of climate change on smallholders [41]; impacts of climate variability household food availability [42] and the predicaments of rural development interventions in Tigray Region post in 1991 [43].

These studies used various methodologies and techniques to investigate the status of food security and its determinants, impacts of policy or interventions on food security, impact of specific shocks on food in/security, impacts of micro-finance to food insecurity, the relationship between adoption of improved best practices and food in/security. However, food security status is experienced

[1] https://www.who.int/news/item/06-07-2022-un-report–global-hunger-numbers-rose-to-as-many-as-828-million-in-2021.

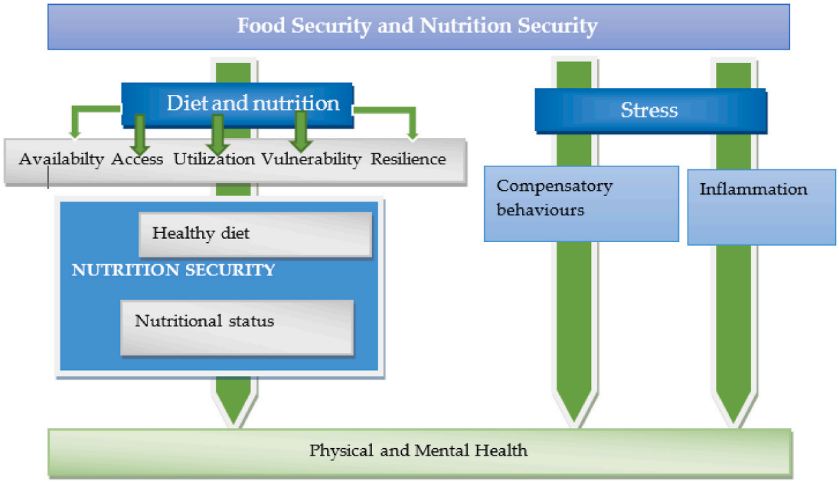


Fig. 1. Figure1: Food and nutrition security, Adopted from Seligman et al., 2023 [68] and Pieters et al., 2013 [5].

differently spatially and temporally depending on socio-economic status and gender (88; 93; 94,95,96]. Therefore, as the manifestation of inequalities in food security differs in economic status, gender and locations the authors recommended that the research community to focus on social differentiation in Ethiopia to detangle the relationship between diverse inequalities, food and nutrition security.

Besides, food and nutrition insecurities in terms of availability, access and utilization persist for large proportion of the population, including in surplus-producing areas in Ethiopia [44]. Hence, there is a need to increase the production and availability while also ensuring that the poor, the marginalized and the neglected have access to high-quality, safe and nutritionally adequate food. Therefore, the objective of this study are.

- To assess the inequalities in food and nutrition security among PSNP and Non-PSNP;
- To estimate the intensity of nutrition security; and
- To recommend pathways and policy options to fill food and nutrition security gaps in Tigray Region.

This paper will significantly contribute development organizations, government officials, researchers, and decision makers set their targets in Tigray Region so that regional goal level outputs, outcomes, key performance indicators and outputs can be identified. The findings are based on Realizing Sustainable Agricultural Livelihood Security in Ethiopia (REALISE) 2018 baseline data sets. As such, REALISE is a programme that aligns the Netherlands development support with the Government of Ethiopia's (GoE) Productive Safety Net Programme.

The rest of the paper is organized as follows: the next section outlines the literature review on food and nutrition security, conceptual frameworks and empirical framworks of the study. The third s presents the data used in the study including its source, conceptual framework, model specification and estimation strategy applied in the study. Section four presents the result of the study and section five discusses the findings. The last section by summarizesand outlines the policy messages and recommendations derived from the findings.

2. Review of literature

2.1. Food and nutrition security status in Ethiopia

Food and agriculture sectors play primary role in improving household food security and alleviating and preventing malnutrition [45,46]. Agriculture provides the majority of the world's food, employment and income upon which the majority of mankind relies to provide for and support their livelihood [47]. A large number of people, especially the poor, involve directly or indirectly in agricultural activities and derive multiple benefits from its multifunctional character. Given the high level of dependency of many of the world's poor and nutritionally vulnerable people, agriculture sector offers the greatest potential for achieving sustained improvements in the nutritional status of the rural poor [11].

Food insecurity and nutrition deficiency are common phenomenon in Ethiopia [48]. The usual three pillars of food and nutrition security – availability, access and utilization – are still not fulfilled for large proportion of the population, even in surplus-producing areas [49].

Cognizant of these facts, Ethiopia's government has implemented explicit nutrition promotion strategies like the National Nutrition Program and the Nutrition Sensitive Agriculture Strategy to promote nutrition [50]. For example, the Nutrition-sensitive agriculture is a food-based approach to agricultural development that puts nutritionally rich foods, dietary diversity, and food fortification at the

heart of overcoming malnutrition and micronutrient deficiencies [51,52].

The overall objective of nutrition-sensitive agriculture is to make the global food system better equipped to produce good nutritional outcomes [53]. Strategies that focus on food and agriculture are the primary tool for improving the quality of the diet and for overcoming and preventing malnutrition and nutritional deficiencies. In recent years governments and NGOs have promoted and implemented new approaches to a balanced diet [54,55]). The approach stresses the multiple benefits of eating a variety of foods, and recognizing the nutritional value of food for good nutrition and the importance and social significance of the food and agricultural sectors in supporting rural livelihoods, thereby encouraging and equipping consumers to consider their total diet in relation to their preferences, individual lifestyle factors, physiological requirements and physical activity levels.

Studies on nutrition has explained malnutrition continues in countries with seemingly adequate food supplies highlights the need to overcome poverty, marginalization and neglect [56]. Thus, the need to increase foodproduction and availability, while also ensuring that the poor, marginalized and neglected have access to good quality, safe and nutritionally adequate food. These, promote physiological, mental and social development, enhance learning potential, reduce nutritional disorders, and help to prevent diet-related diseases later in life (ibid).

For this reason, nutrition security has emerged as one of the most important evolving concepts and facts. Thus, malnutrition is a serious global problem with devastating consequences, and governments have established national nutrition targets based on World Health Organization (WHO) recommendations to improve people's nutrition [57,58]. A comprehensive implementation plan for maternal, infant and young child nutrition in 2025 has been developed, with the goal of ending hunger and malnutrition in all forms. Moreover, the Sustainable Development Goals (SDGs), adopted in 2015, include a target of ending all forms of malnutrition by 2030, and plans are well underway for a potentially landmark nutrition for growth (N4G) and the formulation of strong compact for nutrition [58].

Malnutrition is a major development challenge in Ethiopia. For example, stunting and wasting are serious malnutrition problems in Ethiopia. According to recent reports, about 40% of children are under the age of five suffer from stunting due to chronic and cyclical malnutrition [35]. Household food insecurity, hunger and under nutrition remain critical issues; the poor nutritionfor women and children has long been a consistent problem in Ethiopia [59]. However, while stunting and underweight rates have decreased over the past decade, as mny as 44% of children under the age of five remai stunted and 29 percent are underweight [60]. Lack of dietary diversity and micronutrient-dense food consumption, and problematic child feeding practices all contribute to the high rates of child under nutrition. One quarter of women of reproductive age are undernourished, leaving their children predisposed to low birth weight, short stature, lower resistance to infections, and higher risk of disease and death.[2]

Children in rural areas are more likely to be stunted (46%) than those in urban areas (36%), and the Tigray Region is more severely affected [35]. Nutritional status in children under age five, with 38% considered short or stunted for their age, and 18% are severely stunted. Furthermore, some nutritional and health indicators reveal that the country has high level of food insecurity. Consequently, Ethiopian development plans including the current AGP, NNP, and Nutrition Sensitive Agriculture Strategy have focused on nutrition. Furthermore, studies found that the household dietary score intensity, and dietary diversity score and food gap months in Tigray Region are low [61].

Given these facts, nutrition-sensitive interventions such as homestead production of diverse, nutrient-rich foods, coupled with behavior change communication, have the potential to improve the nutritional status and health of rural agricultural households, particularly among women and young children [54]. Given the scarcity of trained health care providers, in many developing countries, engaging agriculture and health extension workers in these communities may be an effective way to deliver nutrition-sensitive interventions [62].

Appropriate and coordinated nutrition action enables for the creation of a healthy and productive labour force, which is vital to ensuring rapid social economic development and guaranteeing food security. Besides, proper child and mother care practices, provision of adequate health services, and maintaining appropriate sanitation and hygiene conditions are all essential for optimal nutrition [63]. The low-level cost of production and area required for fruits and vegetables by smallholder farmers especially for poor households, provides an opportunity to mainstream nutrition activities through nutrition education and home gardening development, thereby reducing malnutrition and related risks [54,64,65].

Low intake of fruits and vegetables is a major cause of micronutrient deficiencies in the developing world. The low in the consumption of fruits and vegetables (FVs) on menus is associated with an increased risk of micronutrient deficiencies, heart disease, cancer, and obesity [57]. Though nutrition guidelines recommend at least two servings of fruits and three servings of vegetables per day, amounting 400 mg, low-income countries consume fruits and vegetables at a low rate due to their affordability [66]. Small-scale homestead production of micronutrient-rich foods, when combined with nutrition education, can have a greater impact on household income and nutrition. Thus, it improves the frequency of eating vegetable and fruit products and taking the home garden as a source of income to full the food gaps especially to buy different food stuff from the market which supports the household to consume more vegetables and improve the health status of the household especially the poor households [56]. However, while governmental and non-governmental organizations consider nutrition and gender in all aspects of development activities, the range of developing home gardening and nutrition education is very limited [67]. Fruits and vegetables are important components of a human diet and vegetables' contribution as a source of fiber is very important, especially in low fiber diets [68]. Although edible fibre is not a nutrient and absorbed by the body, it is a component of vegetables that assist in the movement of food through the alimentary canal by aiding the

[2] Ethiopia: Nutrition Profile, (updated May 2021)(usaid.gov).

muscular action of the intestines, thereby preventing constipation and helps to satisfy the appetite [69].

2.2. Conceptual and Theoritical Framewroks

Policy makers and global leaders have focused on food and nutrition security, especially since the 1996 World Food summit. Food and nutrition security was defined as the situation "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life", which comprises two dimensions: the status of food and nutrition and the stability of that status [70]. The USDA defines food security as the food access that promotes an "active, healthy life" [69] that focu s on households' ability to access nutritionally adequate and safe foods. This definition ignores the nutritional value [71]. As the concepts of food and nutrition security evolved, researchers started to develop conceptual frameworks that linked the two. The status of food and nutrition security is determined by food availability, food access and food utilization of an individual or a household, while stability is determined by vulnerability and resilience to food and nutrition security [5]. Some concepts detangled the relationships between food security and nutrition security, as well as the physical and mental health consequences, highlighting the role nutrition security plays as a critical mediator in the relationship between food security and health [72].

This study focuses on the food and nutrition components, rather than the health aspects. Given the concept of food and nutrition security as affected by different factors, it is more appropriate to illustrate how food availability, access, and utilization are interlinked. Food availability is defined as to the extent to which food is available to households (for example in local shops and markets), in terms of both sufficient quantity and quality, as determined by domestic food production, commercial food imports, and food aid [73]. All drivers and determinants that affect food supply influence food availability [74]. It is important to point out that socio-economic status and gender differences influence food availability such as land ownership and access to agricultural inputs such as credit, pesticides and technology [75].

Food access is an important component of food and nutrition. The opportunity to obtain sufficient quantity and quality to ensure safe and nutritious diet by a household is considered as household level food access achieved [73]. Then food access is determined by access to the necessary resources required to acquire food like household resources, food prices, food preferences and socio-political factors such as discrimination and gender inequality including labour, human capital and natural resources [5,76]. Household characteristics like education level, social and economic status (being PSNP in our case), gender inequality (being male headed and female headed) etc. are all major determinants of food and nutrition security [77,78,79].

Food utilization refers to an individual's dietary intake and ability to absorb nutrients from the they eat [5]. Thus, to satisfy not merely subsistence needs, but also energy needs for daily activities, notably income generation, the food consumed by an individual must be of sufficient quantity and quality [80]. Calorie and micronutrients are used to measure food utilization. Thus, the utilization of at least more than seven food groups is considered as a proxy for nutrition security. In fact, income of the household is one of the determinants of food utilization; as households grow richer, they tend to shift to more diverse diets that include larger proportions of these high-value food products [81], which leads to improvements in family members' food and nutrition status by improving their dietary intake, while gender inequality and socio-economic status are the major determinants [5].

The second important dimension of food and nutrition security is stability, which is directly linked with the effects of shocks on livelihoods and the ability to recover easily or pushed into a poverty trap. Therefore, households adopt different livelihood strategies to cope with the negative impacts of the shocks [82,5]. These strategies may include selling assets, withdrawing savings, migrating, seeking temporary employment, withdrawing children from school and reducing the diversity of the diet, reduce consumption, etc [83,84]. To build resilience and reduce vulnerabilities, households adopt strategies both ex-ante and ex-post measures [85], such as diversification and adoption of improved varieties (early maturing, and/or late maturing based on the context of weather variabilities) [82]. Therefore, the aim of this study is to show the current status of food and nutrition security in Tigray taking in to consideration socio-economic differences, gender, vulnerability to climate change and access to best practices and innovations, and what this means for food and nutrition security. This study also seeks to unravel the nexus between food and nutrition variables and how they can influence effective policy formulation along food and nutrition security nexus in the region.

2.3. Emperical framework

Many studies have been conducted on food and nutrition security. As food and nutrition security are complex by their nature, different factors contribute to and determine food security. Food security status is experienced differently spatially and temporally by different socio-economic status and genders [[10,86–91]. Food security affects households differently. For example, shocks are experienced differently-based on economic status [92]. The response of sustainable improved practices differs across agro-ecologies and has an impact on food security and economic outcomes [[93–95]. Besides, idiosyncratic factors like price shocks have varying effects on households' food security [39]. The manifestation of food security inequalities varies by economic status, gender and location [89].

Rainfall variability has an impact on household food security and climate adaptation strategies for food production [96,97]. Socio-economic factors influencing yield and food security include like access to credit, education and asset ownership [[98–102]. Differences in service provision and response to services have also been demonstrated. For example, agricultural extension services are strongly biased towards men, limiting women's access to inputs, information and technologies [88,103] resulting in low production and greater vulnerability to food insecurity. Studies on the impact of microfinance on the capacity to overcome food insecurity showed that female clients were significantly less likely to receive food aid [104].

Access to natural resources like access to productive resources, irrigation and other water harvesting technologies all have an impact on food security [31,102,105]. Soil and water conservation practices affect yields, income and food security [106]. Most on vulnerability to food insecurity are often highly context-specific, offering generalizable findings by identifying correlations between levels of food insecurity with sets of variables (land size, livestock holdings, family size, income, educational attainment, etc …) suggesting that there is a need to diversify the questions posed, including social conditions that relate to vulnerabilities and food security status. It appears that more in-depth, qualitative studies is required in this area [89]. However, socioeconomic settingsmust be studied not only to help improve the agricultural sector, but also to understand the nature of the problem across the different socioeconomic segments of the population [10]. Much more work is required to understand how all of these factors interactand how they affect food security vis-a-vis. As outlined above, there is a need to conduct in-depth research on food and nutrition security in order to adapt to a changing climate while taking gender, socio-economic, and other factors into account.

3. Materials and methods

3.1. Description of the study areas

The Tigray Region is located in northern Ethiopia ($12^0$15′N and 14^0 57′N latitudes and $36^0$27′E and $39^0$59′E longitudes); it has six administrative zones with a total area of about 53,000 km^2. The total population of Tigray is estimated 7.2 million. The land cover and use type in Tigray is 36.2 % bush and shrub lands, 28.2 % cultivated land, 22.8 % grassland and about 10.8 % other land uses [107]. The region has diverse topographic features (about 39 % midland, 1800–2400 masl; 53 % lowland, 1400–1800 masl; and 8 % highland, 2400–3400 masl), and it is classified into three agro-ecological zones: 67 % dry; 24 % moist and 9 % wet [107]. The mean annual rainfall ranges from 500 to 1000 mm (ENMA, 2007). Tigray is located in Africa's dry lands, called the Sudano-Sahelian region [108].

This study was conducted in three PSNP woredas in Tigray: Emba Alaje, Raya Azebo and Saesie Tsaeda emba. Emba Alaje district (*woreda)* is located in the southern zone of Tigray Region and consists 20 rural and 1-urban kebele. It is located at $13^0$37′ N latitude and 39^0 08′ E longitude, with an average altitude of 2604 m.a.s.l. The district has a total population of approximately 107,972, with 52,844 (48.9%) men and 55,128 (51.1%) women, and a population density of 140.6 per km,[2] considerably higher than the national average of 73.9 per km^2 [109]. The Woreda had 24,784 households with a total area of 767.2 km^2(78,720 22 ha) and total cultivated land of 22457 ha [110]. Cereal crops account for 65.4% of the total cultivated land in this woreda. About 65% of farm households raised both crop and livestock, with 33.63% only growing crops. Emba Alaje's soil is mostly Lithic Leptosols, which are typical in Ethiopia [111]. The district receives an average of 912 mm of rainfall per year, with daily average temperatures ranging from 9 to 23^0c. Wheat, barley and faba bean are among the district's most important crops [111]. The climate in Emba Alaje Woreda is 30 % highland (*dega*), 41% midland (*weina dega*) and 29% lowland (*kola*). The main rainy season extends from late June to mid-September. The distribution of rainfall, however, ishighly variable, and its onset is often untimely and irregular [112]. It is characterized by recurrent droughts induced by moisture stress. Crop growing period typically last 45–120 days. Mixed type of farming (both crop production and livestock rearing) is practiced in the district. Barley and wheat are the dominant crops grown in Emba Alaje district mainly for home consumption, but legumes and pulses are also planted to serve in crop rotation and soil fertility management [113]. Crop growth begins in June, and crop harvest lasts until November, under normal conditions. Livestock production makes a significant contribution to the household economy through the sale of animals and animal products. Beekeeping is also popular among households close to homesteads and in protected areas [113].

As the Southern Tigray has both highlands constitute a large part of Alaje, Endamehoni and Ofla woredas, whereas the lowland includes the Raya Alamata and Raya Azebo woredas, we selected two representative agro-ecologies from southern zone. Food insecurity has been the major challenge in the region for several decades, owing to agriculture's reliance on erratic rainfall and lack of applied technology. The Raya Azebo woreda is dominated by rainfed agriculture, followed by degraded shrubland. Raya Azebo Wereda is located in the Southern Zone of Tigray, which is low-land agro-ecology. The GPS coordinates of the woreda are 12° 46′ 27" - 12° 51′ 8″ W latitude and 39° 34′ 6" - 39° 55′ 19″ E longitude, with an altitude of 1500–2300 masl and average temperature rangings from 16^0C to 27^0C. The woreda is characterized by erratic and insufficient rainfall rangeing annually from 400 to 600 mm. About 90% of the Woreda population lives in rural and semi-urban areas, and their livelihoods depends on agriculture, which employs about 91% of the rural population [114].

Saesie Tsaeda-emba District located in eastern Zone of Tigray National Regional State at the north eastern edge of the Ethiopian highlands 976 km north of Addis Ababa (capital of the country) situated between 14° 11′ 14″ N latitude and 39° 33′ 50″ E longitude. The district is one of the ninedistricts in the Zone with 27 peasant associations. The district has a total population of 153,003 (48.5%, 51.5% male and female respectively) and 35,179 households, for an average of 4.35 people per household [115]. 86.4% of the total population live in rural areas. Saesie Tsaeda-emba covers an area of 2511.47 square kilometers, and has a population density of 60.92 per km^2 [115]. Altitude of the district ranges from 2357 to 3000 m.a.s.l. with 96% of it being Dega (highland), and it has a semi-arid climate with annual rainfall of 350–500 mm, and temperatures ranging from 13 to 20 °C. The rainfall is predominantly unimodal from June to September, with high temporal and spatial variability. The area's mountainous and hilly topography, torrential rainfall, and low vegetation cover all contribute to severe soil erosion [115].

3.2. Study approach

The primary objective of this study was to investigate food and nutrition security status under changing climate while taking

gender, socio-economic, and other factors into account that contribute to improving food and nutrition security in the PNSP woredas in Tigray Region of Ethiopia. Then, woredas were selected based on their type (being REALISE research woreda), as the research woredas (Emba Aleje and Saesie Tsaeda Emba) are representative of the scaling woredas and food and nutrition insecure woredas in Tigray using systematic sampling. However, Raya Azebbo was considered because of its agro-ecological zone of the area is lowland and it is representative for other similar agro-ecologies such as Raya Alamata. Consequently, a cross-sectional research design was applied by taking a cross-section of the PSNP and Non-PSNP households, as such research approach is helpful to obtain the overall situation at the time of the study period. This enabled the researchers to examine the status of food and nutrition security, the difference in socio-economic status, the livelihood strategies adopted by the households to withstand shocks and risks, and assess the extension services availability as these factors are drivers to food and nutrition securities. To achieve the intended objectives, the researchers used quantitative research approaches to collect data from the selected households using questionnaire.

3.3. Sampling size and techniques

The southern and Eastern zones of Tigray have the highest levels of food and nutrition insecurity. REALISE Program chose ten woredas with high level of food and nutrition insecurity. Then, woredas were selected based on the above determined criteria indicated at 3.2. Regarding the sampling processes, two kebeles were randomly selected from the selected woredas and *gots* (sub-kebeles) were considered during data collected. We collected a list of all households in the Kebele (both PSNP and N-PSNP) from WoA and Food Security for cross checking. Hence, the researchers used the list of all households as a sampling frame, but only those that on agriculture. Finally, a sample of 50 households per Kebele from PSNP and Non-PSNP based on their proportion to size, as well as a total of 100 households from each woreda, were drawn to get representative sample households for the selected woredas. Besides, the food insecure households were categorized as destitute, food insecure and transitory, so that the sample was proportional to size to avoid misinterpretation and bias if the sample came from one of the above groups. Male and female counterparts were randomly selected in proportion to their size. The sampling procedure is indicated in Table 1.

The samples were then drawn based on their probability proportion to size (PPS); however, we used a 70:30 ratio for PSNP and Non-PSNP whenever the proportion of Non-PSNP is greater than the PSNP beneficiary households in the study kebele to get deeper insights for food insecure households. Moreover, the men and women headed households in all categories were calculated using a probability proportional to size. The sample households were then selected at random from the sampling frame for each group.

3.4. Ethical considerations

Before the data were collected from randomly sampled household heads, all participants provided verbal consent as clearly indicated on the questionnaire. All of Mekelle University's and BENEFIT-REALISE's ethical clearance codes and conducts were considered. Socio-economics experts supervised the data collection process. Furthermore, data were collected on normal days to avoid any bias caused by fasting days in the study areas. The study seriously takes note of the various ethical issues and considerations in collecting, organizing, and analyzing data. Thus, while undertaking the study, proper acknowledgment of sources, informant consent and anonymity whenever required is strictly adhered and are avoided.

3.5. Modeling

Different have already developed and used different food and nutrition security measures [116–118]. Besides, new approaches using network analyses that focused on social capital and networks were employed to show relationships between how to mitigate shocks that affect food security [119] and how different social networks play different roles and have unique impacts [120]. Using such approaches, it was recomended that these networks be assessed in terms class, religious and ethnic adherence, and political affiliation [89].

It is broadly explained that the measurement of food security is diverse and multiple in nature based on the goals of the research. For example, the FAO Index is used to measure at a global scale, but referencing national scale development indicators [121] while the International Food Policy Research Institute (IFPRI) employes Global Hunger Index[3] and others use anthropometric data to measure the state of food security [122]. In recent years combination of qualitative and quantitative data sets has been developed to measure food security levels, as integration using different units of analysis has become an issue [123]. As described earlier, till now there is no a composite measure of food security [124] as it needs to employ different measures to capture the dimensions of food security at different levels such as at household and/or individual [125,123]. Food insecurity and hunger are measures of aggregate food supplies or variables that correlate with food insecurity. These measures often fail to accurately reflect individuals' true deviation [126].

Food security status can be measured using different methods, including the Coping Strategies Index (CSI), the Reduced Coping Strategies Index (rCSI), the Food Consumption Score (FCS), the Household Dietary Diversity Score (HDDS), and the Household Hunger Score (HHS), which serve as proxy measures for acute food insecurity and nutrition security. We used the Household Dietary Diversity Score (HDDS) as a proxy measure to nutrition security, as our data is 24 h recall [127,128] and food gap months as proxy for food security, as used by different authors [129,130]. The advantages and drawbacks of all food and nutrition security measures were

[3] http://www.ifpri.org/topic/global-hunger-index.

Table 1
Sampling procedures and sample households.

Kebele	PSNP STATUS												Total HHS		
	PSNP									Non-PSNP					
	Wealth									Male	Female	Total			
	Destitute			Insecure			Transitory								
	Male	Female	Total	Male	Female	Total	Male	Female	Total				Male	Female	Total
Sesat	98	287	385	41	81	122	23	41	64	963	183	1146	1125	592	1717
Tekea	83	173	256	151	205	356	31	8	39	1461	172	1633	1726	558	2284
Werabayu	520	738	1258							571	351	922	1091	1089	2180
Wargba	152	416	568	116	129	245	17	34	51	580	281	861	865	860	1725
Saz	244	219	463						0	738	305	1043	982	524	1506
M/megelta	84	234	318	73	87	160	31	32	63	652	276	928	840	629	1469
Sample households															
Sesat	6	18	24	3	5	7	1	2	3	13	2	15	23	27	50
Tekea	4	9	13	7	12	19	2	1	3	13	2	15	26	24	50
Werabayu	12	17	29							13	8	21	25	25	50
Wargba	4	12	17	3	5	8	1	1	2	17	8	25	25	25	50
Saz	18	17	35							11	4	15	29	21	50
M/Megelta	5	15	20	5	6	11	2	2	4	11	4	15	23	27	50

clearly indicated by Ref. [123], and we exclude this part because it is not the objectives of this study. This study employes three categories to assess dietary diversity for households: low dietary diversity category (≤3 food groups), medium diversity category (4–6 food groups) and high diversity category (≥7 food groups), as used by different authors [127,128] (see Fig. 2).

The Principal Component Analysis (PCA) method was employed to construct the household asset index; a similar approach was employed in different studies [131]. The authors incorporated asset ownership and household characteristics to create an asset index that serves as a proxy for long-term household welfare. To construct the household asset index shown in Fig. 3, we consider the number of rooms occupied by the household, farm tools owned, animal holding measured in Tropical Livestock Unit (TLU), and lighting source.

The Principal components coorelation coefficients were then calculated using the assets owned to construct eigenvectors. After estimating the Kaiser-Meyer-Olkin (kmo) measure of sampling adequecy, which was 60%, all coeficients were above 50%. Using the eigenvector coeeficients, we construct a function based on their respective values as indicated in the formula below.

$$f(x)_1 = a_1 * X_1 + a_2 * X_2 + \ldots + a_n * X_n$$

$$f(x)_2 = b_1 * X_1 + b_2 * X_2 + \ldots + b_n * X_n$$

$$f(x)_n = n_1 * X_1 + n_2 * X_2 + \ldots + n_n * X_n \quad (1)$$

Where $f(x)_1$ is the function costructed from eigen vector; a_1, a_2 *and*..... a_n are the coefficents of the first principal compont for the variables $X_1, X_2 \ldots$ *and* X_n; $f(x)_2$ is the function costructed from eigen vector ; b_1, b_2 *and*..... b_n are the cofficents of the second principal compont for the variables $X_1, X_2 \ldots$ *and* X_n; $f(x)_n$ is the function costructed from eigen vector; $n_1, n_2 \ldots n_n$ are the coefficients of the nth principal component for the variables $X_1, X_2 \ldots$ *and* X_n.

3.6. Data collection and analysis

The National PMU designed a questionnaire that addresses socio-economic status, institutional settings, demographic factors, food security, nutrition and gender related issues for both PSNP and Non-PSNP households. The questionnaire was then reviewed by multidisciplinary teams at the national level. Finally, pre-test was done, and the questionnaire was modified accordingly.

Data collectors were trained at the national level for five days and pre-test of the questionnaire was made to verify its adequacy and completeness. Meanwhile, the pre-test enables us to measure enumerators level of competency. Accordingly, support was given to the selected enumerators based on their Computer Assisted Personal Interview (CAPI) experience. Finally, enumerators received a briefing on the finalized questionnaire to ensure clarity. Quantitative data sets were collected using CAPI from 300 households using face to face interview using CSPro. Data were collected in October and November 2018.

Data were properly managed and cleared by Programme Management Units (PMU). However, it was also checked at cluster level based on the existing circumstances. Data that needs clarification was triangulated and checked, and the results were consistent with other regional and national figures. PMU and cluster experts analysed the data using statistical software such as SPSS and STATA 14.

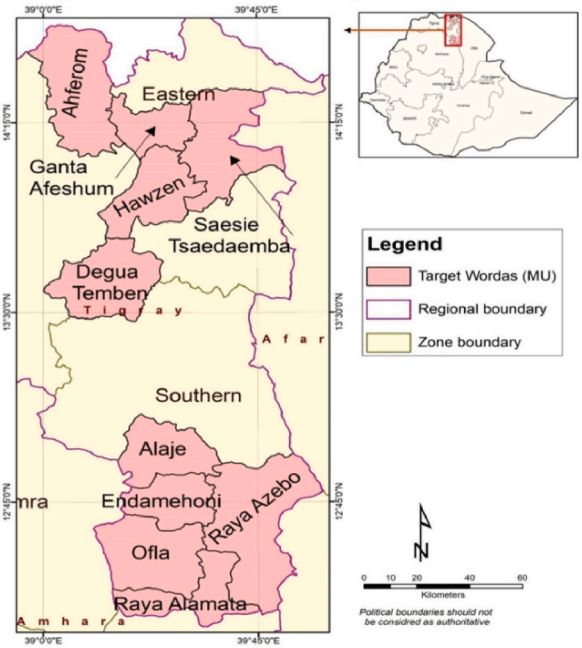


Fig. 2. Figure 2: Study areas.

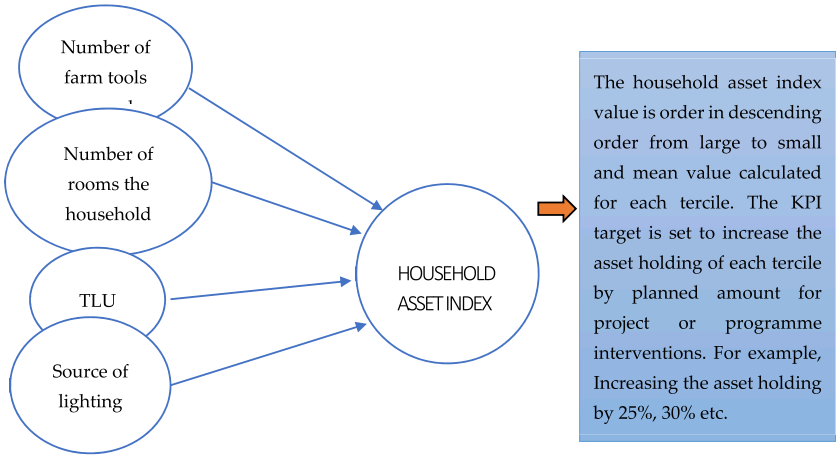


Fig. 3. Diagrammatic Representation of household asset index.

To analyze data and interpret results, both descriptive and inferential statistics like percentages, mean, *t*-test and chi-square were used, and the findings were presented using graphs and tables. To analyze the food security status, we take food gap months as proxy for food security in our case. Furthermore, we used the Household Dietary Diversity Score (HDDS) as a proxy measure to nutrition security as our data is 24 h recall as employed by different authors [127,128].

4. Results

This paper is based on the results obtained from 300 household heads (60% PSNP and 40% Non-PSNP heads of households), of which 40% and 60% of the PSNP households were male- and female-headed households, respectively, and 69% and 31% male- and female-headed households were Non-PSNP households, respectively. In Ethiopia the proportion of male and female headed households is 76.4 and 23.6%, respectively [161] Data were collected from three systematically selected *woredas* (districts) namely Emba Alaje, Saesie Tsaeda Emba, and Raya Azebo, which represent highland, midland and lowland agro-ecologies, respectively.

4.1. Socio-economic status of the households

The results shown in Table 2 reveal that the average family size in PSNP and Non-PSNP households was 4.0 and 4.1, respectively. This shows that the family size did not vary by beneficiary status and, with the two groups having almost similar family sizes, with the exception of Non-PSNP households being slightly larger. However, the household size is lower than the national average of 5.29 in PSNP areas [132]. However, the land ownership differs between the two groups. The mean difference in land ownership is 0.23 ha, which is nearly equivalent to one kert (timad). PSNP and NPNP households owns an average land of 0.521 and 0.749 ha, respectively. This is quite below the national average landownership of 0.7 ha [162]. The results further showed greater variability in the total area of land shared out and shared in by the households. It seems that the majority of PNSP households own reasonable amount of land,

Table 2
Description of households' characteristics and socio-economics conditions.

Characteristics		Beneficiary status			**Total (Avg)**	*t*-test
		Non-PNSP	PSNP			
Family size		4.1	4.01		4.05	0.2991
Age of the household heads		49.62	47.82		48.54	−0.9295
Owned land (ha)		0.75	0.52		0.64	−4.4002***
Shared outland (ha)		0.48	0.47		0.48	−0.192377
Shared in land (ha)		0.82	0.41		0.61	−2.6694***
Rented in land (ha)		0.13	0.00		0.06	NA
Total area of land that the HH Operated(ha)		1.25	0.53		0.89	−2.7536***
					Chi-square (χ2)	
Education level	Illiterate	64 53.3%)	131 (72.8%)			11.9658
	Read and write	56(46.7%)	49(27.2%)			
Primary occupation	Agricultural farmer	111(92.5%)	168(93.3%)			1.0887
	Others	9(7.5%)	12 (6.7%)			
Headship (count and percentage)	MHH	FHH	MHH	FHH	300 (100%)	24.5273***
	83(27.67%)	37(12.33%)	72(24%)	108(36%)		

***, ** and * significance at 1, 5 and 10% respectively; NA= Non-Applicable.
Source: Own survey (2018)

which is half a hectare. However, given that the majority PSNP households are female headed households, it is not surprising that they shared out 0.47 ha which is almost nearest to what they own. On the other hand, the PSNP households shared about 0.4 ha of land. The implication is that the female headed households are shared out their land, because they are unable to plough it. In contrast, male headed households are shared in land to overcome land shortage.

Non-PSNP households share nearly twice as much land as their PSNP counter parts. For this reason, the Non-PSNP households operate 1.25 ha on average, while the PSNP operate only 0.53 ha, which is by far less than the Non-PSNP.

The education status of the households indicates that about 73% of the PSNP are illiterate, while 27% of them are able to read and write (including religious and other non-formal education). In contrast to PSNP households, the Non-PSNP have a balanced education level (47% literate). The primary occupation of the respondents' was agriculture. However, agriculture was the second means of livelihood for some of the respondents, who engaged in in Non-agricultural labour (casual labour), trade, self-employed nonfarm enterprise and other activities, as indicated in Table 2.

The landholding status of the PSNP and Non-PSNP households was disaggregated by gender, and male-headed Non-PSNP households had an average land holding of 0.827 ha, followed by male-headed PSNP households, who owned 0.622 ha each. The land holding of the Non-PSNP FHHs is on average 0.574 ha, while that of PSNP is 0.452 ha. The gender of the household is significantly related with being PSNP beneficiaries and Non-PSNP households.

The descriptive statistic shows that the sampled households own on average 2.07 TLU, 1.51 rooms which is quite below the national average of 2.1 manipulated from the Mini Demographic and Health Survey 2019 Ethiopia [133], 1.43 hoe, 1.26 ox plough, and 1.71 sickle. Solar (63.7%) was the most commonly used lighting source, followed by electricity (17.3%) and batteries (14%). The household asset index was constructed using the asset and lighting data. The details of these variables used for asset construction is detailed in Table 3.

The average TLU ownership also showed a significant difference among PSNP and NPSP. According to our findings, the PSNP has an average of 1.14 TLU, while the Non-PSNP has a value 3.46. Thus, the mean difference in livestock ownership between PSNP and Non-PSNP is 2.32, which is highly significant (t-value = −7.856). The mean TLU for the whole sample is 2.08. The household asset index for Tigray Region was 2.16, which is nearest to the national average.

Asset ownership is the proxy for wealth and the household's capacity to withstand shocks, which is determined by the assets owned and corresponding income. To maintain or improve their livelihoods, including asset protection (from sale) and formation, household members may seek casual work and/or migrate to towns to get additional benefits to support their respective household members. Likewise, as revealed in Table 3, 35.6% of PSNP households engaged in income-generating activities as daily labourers, whilethe Non-PSNP figure is 38.3%. The values are almost similar for the groups, and the level of migration for work showed similar figures with, lower levels of participation in such activities.

The limitation with off-farm activities is that all PSNP households participate in public work activities, which are a proxy for off-farm activities and were not considered as alternative. This lowered the value of PSNP household participation as wage labourers, though the PSNP programme is an opportunity cost for the PSNP households during the off season as indicated in Table 4.

4.2. Food and nutrition security status in Tigray Region

The results showed that about 90%, 83%, 83%, 65% and 51% of the respondents experienced inadequate food availability in the months of August, September, July, June and October respectively. Moreover, 44%, 22%, 8% 5% and 1% of the households are food insecure fin May, March and November, February, January and December respectively (Fig. 4). The graph showed bell-shaped food availability months, with at least half-year food shortage occurring at the regional level. August is the month with the most food shortages, followed by July and September. Most of the households experience food shortages during the months of June and October.

Table 3
Households' asset ownership.

Asset holdings	Beneficiary status		Mean	*t*-test
	Non-PNSP	PSNP		
Hoe/machete	1.58	1.31	1.43	2.4799***
Ox plough	1.36	1.15	1.26	2.6933***
Sickle (Machid)	2.03	1.43	1.71	4.6289***
Number of rooms the household occupy[a]	1.72	1.37	1.51	3.7574***
TLU	3.46	1.14	2.07	7.8540***
Asset Index	2.46	1.95	2.16	5.8426***
Asset Index MHH			2.28	2.7909***
Asset Index FHH			2.03	
Sources of lighting		Chi-square ($\chi 2$)		
Kerosene (count)	2	13	15 (5%)	7.1402*
Battery (count)	13	29	42(14%)	
Electricity (count)	21	31	52(17.3%)	
Solar (count)	84	107	1191(63.7%)	

***, ** and * significance at 1, 5 and 10% respectively; NA= Non-Applicable.

[a] including bedrooms, living rooms, and rooms used for household businesses.

Source: Own survey (2018)

Table 4
Off-farm activities engagement by the households over 12 months.

Particulars	Participation	PSNP status				Total		Chi2 (χ2)
		PSNP		Non-PSNP				
		Count	%	Count	%	Count	%	
Participation as wage labourer	No	116	64.4	74	61.7	190	63.3	0.2392
	Yes	64	35.6	46	38.3	110	36.7	
Migrate for work in the past 12 months for more than 6 months	No	170	94.4	115	95.8	285	95.0	0.2924
	Yes	10	5.6	5	4.2	15	5.0	

Source: Own survey (2018)

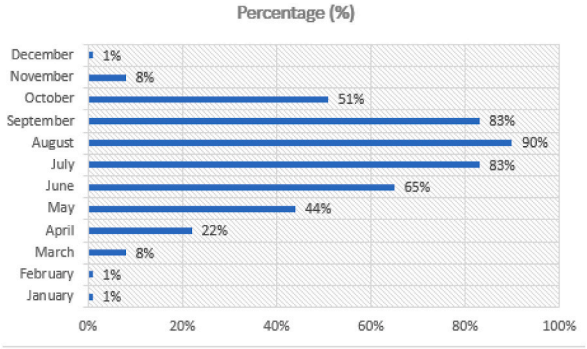


Fig. 4. Food gap months of the sampled households.

On contrary, the adequate food months for the households includes the month of December, January, February, March and November.

In recent years, nutrition security is also among the top development challenges in both developed and developing world. The Dietary Diversity Score (DDS) and the Intensity of Household Dietary Diversity Score (IHDDS) which are the proxy for nutrition status indicates that the mean DDS for male headed households is 6 for both PSNP and Non-PSNP. The DDS for FHH were 5.01 and 5.51 for the PSNP and Non-PSNP respectively. The Non-PSNP female headed households are better off in terms of dietary diversity than the FHH PSNP households. The results further showed that the DDS of the PSNP and Non-PSNP households is 5.35 and 6.03 respectively. It is not surprising that the Non-PSNP are better off than the PSNP in terms of dietary diversity in Tigray as clearly indicated in Table 5.

The results reveal that the food gap months of the PSNP households for the 1st tercile was 0.58 months (17.4 days) while second

Table 5
Dietary diversity scores and average food gap months.

Dietary Diversity Score	Beneficiary status		**Mean**	*t*-test
	Non-PNSP	PSNP		
HDDS	6.03	5.35	5.63	3.9574***
HDDS MHHs	6.26	5.85	6.07	1.8892**
HDDS FHHs	5.51	5.01	5.14	1.8001**
Food gap months	2.26	3.72	3.13	−4.8430***
	Household Headship			
	MHH	FHHS		
HDDS	6.07	5.14	5.63	5.5925***
HDDS for PSNP	5.85	5.01	5.35	3.9351***
HDDS for NPSNP	6.26	5.51	6.03	2.5842***
Food gap months	2.46	3.85	3.13	−4.7243***
Total Regional DDS				
Low HDDS (count & %)	23(8%)			
Medium HDDS (count & %)	185 (63%)			
High HDDS (count and %)	88(30%)			
Food gap months	Mean Food gap months			
Percentile	PSNP	Non-PSNP	For Tigray (whole sample)	
1st (33% percentile)	0.58	0	0.09	
2nd (66% percentile)	2.3	0.73	1.61	
3rd (99% percentile)	3.72	2.26	3.13	

***, ** and * significance at 1, 5 and 10% respectively.
Source: Own survey (2018)

tercile was 2.3 (69 days) months. The food gap months for the third tercile for the PNSP households indicates 3.72 months (111 days) which is huge as indicated in Table 5.

The food gap months – Months of Adequate Food provisioning indicator also shows the average food gap months in Tigray for the whole sampled households was 3.13(94 days) months. The food gap months for the 1stterciles is 0.09, while the second and third tercile average food gap months are 1.61 (48 days) and 3.13 (93.9 days) respectively.

The scales of the intensity of HDDS shows considerable proportion of sample households that fall under medium (63%) household dietary diversity score which means the households and their family members consume 4 to 6 food groups followed by high dietary diversity score (30%) which means the households and their family members consume more than 7 food groups. Only 8% were found to be low HDDS in Tigray Region who consume less than 3 food groups. Besides, the HDDS for Non-PSNP was 6.03 and 5.63 for the PSNP households with highly significant difference at 1%. This indicates the Non-PSNP households consume more food groups than the PSNP counterparts. The gendered difference in HDDS also revealed similar results. The HDDS for the PSNP male headed households was 5.85 while 6.26 for the Non-PSNP counter parts which is significantly low level of dietary diversity. Similarly, the HDDS for female headed households revealed that the PSNP female headed households have 5.01 HDDS while 5.51 for Non-PSNP which is highly significant at 5%. The results also revealed that the male and female headed households average HDDS is 6.07 and 5.14 respectively. This implies female headed households have low level of HDDS compared the male headed households.

The mean comparison of the food gap months of the Non-PSNP households is significantly lower than the PSNP counterparts accounted for 2.26 and 3.72 respectively on average. Further, the food gap months of the male headed households is by far lower than the male headed counter parts which accounted 2.46 and 3.85 respectively. The Non-PSNP and men-headed households are better off than the PSNP households in terms of HDDS and lower average food gap months.

The results revealed in Table 6 show that 97.2% of the PSNP consumed cereals. Likewise, almost all Non-PSNP consumed cereals in different forms like injera, bread, pasta, biscuits, kollo, or any other grain products - such as porridge or pasta etc. made from cereal food groups. Thus, both PSNP and Non-PSNP households depend on cereals based staple food for consumption. Like cereal food groups the consumption of root and tuber crops food items is similar for the PSNP and Non-PSNP though about 30% and 33% of the PSNP and Non-PSNP households consumed food items made of these food items.

The consumption of vegetables is more than root and tubers. About 74% of the PSNP consumed vegetables while 88% of the Non-PSNP consumed vegetables. The vegetables consumption of Non-PSNP is better than the PSNP households. However, fruit consumption is by far less than that of vegetables. Thus, about 97% and 93% of the PNSP and Non-PSNP households did not consume any fruit.

Pulses are also other sources of food for the households and about 84% and 91% of the PSNP and Non-PSNP consumed pulses as food items in the region. Oil crops are also consumed by the households and about 72% and 77% of the PSNP and Non-PSNP households used oil crops in different forms of food items.

The findings also indicated that about 95.5% and 92% of the PSNP and Non-PSNP did not consume any meat and meat products within 24 h of the interview period. The same is true for egg as 93% for both PSNP and Non-PSNP did not consume during the interview time. Similarly, the milk and milk product consumption of PSNP is only 7%, while that of Non-PSNP is about 26%. The better milk consumption of the Non-PSNP households may be correlated with higher livestock ownership.

The survey results also indicated that 95.5% and 95% of the PNSP and Non-PSNP consumed other food items like coffee, tea and spice. Almost all the households drink coffee as a stimulant. The sampled households drink coffee using sugar. As a result, almost 60% and 72.5% of the PSNP and Non-PSNP has consumed sugar and/or honey in their food dishes.

4.3. Agricultural resilience

The results indicated that drought is the top ranked common hazard faced by both PSNP and Non-PSNP households. However, the numbers of FHH who are in PSNP have the largest proportion in reporting drought. The second major hazard is erratic rainfall distribution and the third is flooding as indicated in Table 7.

About 91% of sampled PSNP households faced with shocks, hazards and risks. They have lost their crops or suffer significant

Table 6
Food groups consumed by the households within 24 h of the time of interview.

Food items consumed	% PSNP	% Non-PSNP
Cereals (teff, millet, barley, sorghum, maize, rice, wheat)	97.2	99.2
Pulses (beans, peas, lentils, faba-beans, common bean, chickpea, soybean, lentils)	84.1	90.8
Root and Tubers (white potatoes, yam, cassava, enset, sweet potatoes)	30.1	33.3
Vegetables (onion, tomatoes, carrot, cabbage, lettuce, bit roots, garlic, green leafy-veggies, pumpkin)	73.9	88.3
Fruits (water melon, avocado, mango, banana, guava, orange, mandarins, pineapple, apple)	3.4	6.7
Meat (beef, lamb, goat, camel, pork, goose, chicken, liver, kidney)	4.5	8.3
Egg	6.8	6.7
Fish	0.6	0.0
Milk products (cheese, yogurt, milk or other milk products)	6.8	25.8
Oil crops(oil, fat, or butter made from oil crops or foods made from seeds)	72.2	76.7
Sugar and honey	59.7	72.5
Other foods (such as condiments, spices, coffee, tea)	95.5	95.0

Table 7
Common hazards faced by households.

Type of hazard	PSNP					Non-PSNP			
	MHH		FHH		total %	MHH		FHH	
	Count	%	Count	%		Count	%	Count	%
Drought	47	94.0	75	97.4	96.1	50	92.6	23	92.0
Flooding	2	4.0	1	1.3	2.4	1	1.9	1	4.0
Livestock disease outbreak	0	0.0	3	3.9	2.4	1	1.9	0	0.0
Crop pest& disease	1	2.0	4	5.2	3.9	0	0.0	1	4.0
Erratic rainfall	4	8.0	1	1.3	3.9	5	9.3	0	0.0
Frost	1	2.0	0	0.0	0.8	0	0.0	0	0.0

reduction in yield as the result of the aforementioned hazards. Moreover, about 88% of the Non-PSNP has also faced the same impact due to shocks and hazards. Erratic rainfall distribution and flooding are the second and third major hazards respectively.

Though the impacts of the shocks and hazards are common for all groups about 92% PSNP FHHs are severely affected. Furthermore, the impacts of the shocks led the households to depend on aid. Moreover, due to the shocks and hazards the households face food shortage for 6–9 months and less than 3 months. Loss of livestock is another impact of shocks especially for the Non-PSNP households has caused livestock asset depletion as indicated in Table 8.

The result further showed that about 78% of the MHH PSNP households are able to bridge the food gap months in case hazards occurred currently either from own reserve or accessing from the market while only 43.4% of the FHH PSNP households are able to bridge the food gap for two months if hazard occurred currently. The Non-PSNP MHH and FHHs capability to bridge the food gap months if hazards are occurred currently is 84.0% and 61.5% respectively. As indicated in Table 9. This implies that MHHs are more capable to bridge food gap months than FHHs. Thus, FHH are more vulnerable than the MHHs for both PSNP and Non-PSNP as indicated in Table 9.

To cope up the shocks and hazards the farmers have applied different strategies (both reactive and pro-active). However, the reactive coping strategies are more common than the proactive ones (Table 10). These strategies include selling livestock, selling reserved seeds, loan and borrowing and remittance. About 53%, 30.4%, 54.7% and 68% of the PSNP MHH and FHHs and the Non-PSNP MHH and FHHs sold their livestock during shocks and hazards.

The occurrence of shocks has also led to sell the reserved seeds. Hence, this led to sell quality seeds during the occurrence of the hazards and the farmers are forced to buy another seed from the market with unknown seed sources and poor-quality during planting time. It is obvious that seed is one of the major factors of production. As a result, selling saved seed has a multiplier effect on the production directly and loss of generic diversity indirectly. This is because selling the farmers' preferred seeds due to the environmental shocks and risks lead to genetic erosion as it is replaced by unknown seeds which are not preferred by the farmers.

In addition to the aforementioned coping strategies, the farmers also used collecting firewood and making charcoal for money to sustain life during shocks which in fact causes environmental degradation. Other coping strategy like looking for wage labourer was also used by the households. However, the reactive strategies adapted to cope the risks were 93% while the pro-active accounts only for 7% based on the survey results.

Community pursues different types of strategies to build resilience. This includes remittance flow from outside to the community which can improve their resilience during the time of shock and aftermath and transfers. This shows that only 18.8% of the community members received remittance in the last 12 months. This proportion is relatively low and its implication is that the community own buffer against shocks and stressors is inadequate. Moreover, resource transfer is a common phenomenon among community members to cope with unexpected or chronic shocks and stressors. Community members engage in the transfer of food, cash, seed, livestock or other resources. Thus, about 20.8% of the respondent households reported they had received transfer in the last 12 months. The level of

Table 8
Direct impact of shocks on the livelihood of the households.

Direct Impact of hazards	PSNP				Non-PSNP				Rank
	MHH		FHH		MHH		FHH		
	Count	%	Count	%	Count	%	Count	%	
Loss of crop/reduction of yield	44	88	71	92	47	86	23	92	1
Loss of livestock	5	10	7	9.1	9	16	3	12	4
Food shortage <3 months	5	10	3	3.9	4	7.3	4	16	5
Food shortage for 3–6 months	8	16	19	25	6	11	6	24	2
Food shortage for 6–9 months	3	6	3	3.9	1	1.8	1	4	6
School dropout	0	0	0	0	1	1.8	1	4	8
Migration and displacement	0	0	1	1.3	0	0	0	0	9
Damage to assets	0	0	1	1.3	0	0	0	0	9
Dependency on aid	10	20	8	10	6	11	5	20	3
Decreasing food diversity	0	0	1	1.3	2	3.6	0	0	7

Source: Own survey (2018)

Table 9
Periods the households able to bridge food gap months if hazard occurs.

Categories	PSNP				PSNP				Rank	Chi2 (χ2)
	MHH		FHH		MHH		FHH			
	Count	%	Count	%	Count	%	Count	%		
Less than one month	2	4	15	18.1	2	3.6	1	3.8	3	17.2937***
Two months	9	18	36	43.4	7	12.5	9	34.6	2	
Three months or more	39	78	32	38.6	47	84	16	61.5	1	

***, ** and * significance at 1, 5 and 10% respectively.
Source: Own survey (2018)

Table 10
Coping strategies to shocks and hazards used by the households.

Copping strategies	PSNP				Non-PSNP				Total	Rank	Chi2(χ2)
	MHH		FHH		MHH		FHH				
	Count	%	Count	%	Count	%	Count	%	Count		
Sold livestock	25	53.2	24	30.4	29	54.7	17	68.0	95	1	14.0811 **
Sold seed reserve	13	27.7	26	32.9	20	37.7	6	24.0	65	2	
Sold land	0	0.0	0	0.0	1	1.9	0	0.0	1	9	
loan, borrowing	11	23.4	23	29.1	6	11.3	6	24.0	46	3	
Begging	0	0.0	2	2.5	0	0.0	0	0.0	2	8	
Send children to relatives	0	0.0	1	1.3	0	0.0	0	0.0	1	9	
Better crop varieties; seeds	1	2.1	0	0.0	1	1.9	0	0.0	2	7	
Asked for remittances	3	6.4	14	17.7	3	5.7	2	8.0	22	4	
Water harvesting	1	2.1	0	0.0	0	0.0	0	0.0	1	9	
Yield twice a year	1	2.1	0	0.0	0	0.0	0	0.0	1	9	
Collecting firewood and making charcoal for money	5	10.6	7	8.9	2	3.8	6	24.0	20	5	
Other	3	6.4	6	7.6	7	13.2	2	8.0	18	6	

Source: Own survey (2018)

transfer reported in the last 12 months is inadequate.

4.4. Agricultural practices

Table 11 shows about the crops (cereals, pulses and oil and vegetables) grown by the farmers. However, cereals are the dominant crops cultivated by the farmers followed by pulse crops. The productivity of all crops was quite below expectation. However, the regional average yield was much better than our findings due to many reasons. For example, the number of seed varieties was only 12 that was used by the farmers. The largest share takes wheat improved varieties and accounts for 8 (67%). However, only one variety of food barley potato, teff, and tomato was used by the farmers.

Fig. 5 depicts the regional yield gap compared to national and potential yield (on station). Hence, we have observed that the yield in

Table 11
Yield of major crops (qt/ha).

Important crop	Area in Ha	Production (qt)	Yield	CSA Yield for Tigray
Food barley	30.75	247.4	8.30	17.89
Maize	2.66	23.5	9.60	25.59
Malt barley	4.87	28.0	7.14	NA
Sorghum	43.28	434.8	10.17	28.52
Teff	41.77	145.5	3.97	15.37
Wheat	52.59	561.6	10.82	19.83
Chickpea	10.36	39.0	4.20	13.00
Faba bean	8.67	59.6	7.06	16.47
Finger millet	3.50	34.0	9.48	22.66
Grass pea	1.63	11.2	7.10	16.56
Lentil	3.00	8.4	3.06	12.32
Pea	1.77	7.9	4.44	16.30
Garlic	0.13	1.0	4.00	72.33
Onion	4.82	95.5	21.16	NA
Potatoes	2.18	137.5	61.51	77.39
Tomatoes	0.5	39.5	75.81	0.00

Sources: Own survey and CSA (2018)

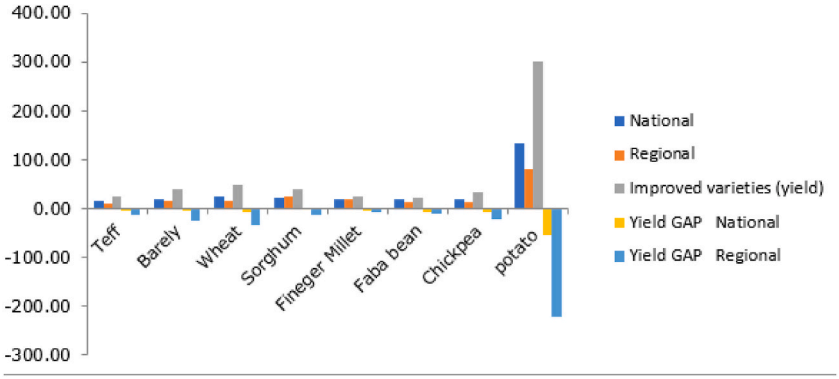


Fig. 5. Regional yield gap for major crops.

the PSNP areas is quite below the potential yield, regional and national averages.

Food and nutrition security depend on the crop production, utilization and marketing. It is obvious that high production can help smallholder farmers to ensure the daily calorie requirement for different crops. As production is not adequate by itself, the amount consumed from the produced grains is also highly important. Smallholder farmers often sell cash crops and seldom grains to buy for household stuff for consumption like salt, oil, sugar and others which are important sources of vitamins, minerals and carbohydrate. The crop production, utilization and marketing of own produced grains may vary based on the households' socio-economic prospects and productive resources endowment.

The findings further revealed that the production and selling of grains such as barley, sorghum, teff, maize, faba-bean, finger millet and grass pea the Non-PSNP is higher than that of PSNP as indicated in Table 12. Thus, the market participation of the Non-PSNP is better than the PSNP may be due to the production variation as it is straight forward that high production is strongly correlated with market participation. The low production was also attributed by small land ownership for the PSNP households.

The productivity of MHH and FHH PSNP households indicates that MHHs have higher productivity (8.92 qt ha^{-1}) than FHHs (7.77 qt ha^{-1}) for barley crop, whereas, FHHs have attained better productivity than MHHs for the Non-PSNP group which accounts 12.19 and 7.05 qt ha^{-1}respectively. For maize crop, the MHH have lower productivity (4.8 qt ha^{-1}) than FHHs (10.4 qt ha^{-1}) which is more than double for the PSNP households. MHHs have more productivity than the FHH counterpart Non-PSNP households which accounts for 13.1 qt ha^{-1} and 8 qt ha^{-1} respectively.

Sorghum is one of the major food crops in the low-land study area. The yield of sorghum was 7.42, 5.74, 14.91 and 10.21 qt ha^{-1} for the MHH and FHHs PSNP and Non-PSNP households respectively. This showed that MHH Non-PSNP households have better productivity than the remaining groups followed by FHH Non-PSNP households. The productivity of teff was very low compared to the regional and national averages like other crops for all groups. The results showed that the productivity of teff was 4.01, 2.9, 4.8, and 3.8, 4.8 qt ha^{-1} for MHH and FHH PSNP and Non-PSNP households respectively.

Wheat is also one of the important cereal crops as a source for both income and food for the households. Its productivity was very low during the study time. It was quite below the national and regional averages. The productivity of Non-PSNP is higher than the PNSP households as indicated in Table 13. The same is true for finger millet crop. But the productivity of sorghum for the MHH Non-

Table 12
Crop production and utilization.

Crop Type	PSNP				Non-PSNP			
	Produced (Qt)	Sold (Qt)	Consumed (Qt)	Saved Seed (Qt)	Prod (qt)	Sold (Qt)	Consumed (Qt)	Saved for Seed (Qt)
Foodbarley	111.85	8.2	95.45	8.2	135.55	20	97.05	18.5
Maize	9.5	0.25	9.25	0	14	0	13.85	0.15
Malt barley	23	1	21	1	5	1.5	3.5	0
Sorghum	95.5	22.6	71.5	1.4	339.25	93	236.69	9.56
Teff	46.9	17	29.5	0.4	98.55	21	74.05	3.5
Wheat	281.75	31.25	228.65	21.85	279.83	52	193.9	33.93
Chickpea	24.55	15.65	7.8	1.1	14.45	5	9.2	0.25
Faba bean	19.35	11.5	7.05	0.8	40.25	23.7	12.55	4
Finger-millet	10.5	0	9.8	0.7	23.5	2	21	0.5
Grass pea	3.25	1	2.2	0.05	7.9	4	2.9	1
Lentil	3.65	2.75	0.85	0.05	4.7	3.3	0.7	0.7
Pea	3	0.4	2.2	0.4	4.9	1.9	1.75	1.25
Garlic	1	1	0	0				
Onion	11.5	11	0.5	0	84	84	0	0
Potatoes	108	106.8	0.6	0.6	29.5	28.5	0.93	0.07
Tomatoes	13	12.5	0.5	0	26.5	26.4	0.1	0

Source: Own survey (2018)

Table 13
Gender-wise productivity difference in major crops.

Crop type	Beneficiary status		Mean	*t*-test
	Non-PNSP	PSNP		
Food barley	8.30	8.30	8.30	0.0284
Maize	12.25	7.6	9.59	3.2469***
Malt barley	7.30	6.67	7.14	−0.2720
Sorghum	13.43	6.18	10.17	17.5413***
Teff	4.50	3.42	3.97	8.8154***
Wheat	11.86	10.16	10.82	17.3867***
Chickpea	3.07	4.88	4.20	−12.8307***
Faba bean	8.99	5.03	7.06	10.8689***
Finger millet	11.11	7.65	9.48	5.5142***
Grass pea	11.07	4.13	7.10	2.05781**
Crop type	Household Headship			
	MHH	FHHS		
Food barley	7.92	8.82	8.30	−2.997***
Maize	9.41	9.92	9.60	−0.2525
Malt barley	9.38	4	7.14	4.6669***
Sorghum	12.94	7.32	10.17	8.1564***
Teff	4.48	3.26	3.97	11.8156***
Wheat	10.65	11.04	10.82	−2.4610***
Chickpea	3.60	4.78	4.20	−4.4521***
Faba bean	8.61	5.25	7.06	6.5358***
Finger millet	9.8	8	9.48	1.3312
Grass pea	12.00	3.45	7.10	3.4142**

***, ** and * significance at 1, 5 and 10% respectively.
Source: Own survey (2018)

PSNP households is higher than the other groups. However, the productivity of Faba bean is better for the Non-PSNP than their PNSP counter factual. The productivity of grass pea for the MHH Non-PSNP households is by far greater than the other groups.

4.5. Agricultural extension services

Agricultural service is an important component in the agricultural extension system in facilitating linkages among input suppliers and end users, creating market linkage, research and extension linkages and consulting farmers in farming practices. The farmers' participation in extension services like training showed that only 16.7% and 14.8% of the PSNP MHH and FHHs participated in training respectively (Table 14). About 81.9% and 73% of the Non-PSNPMHH and FHH respectively did not participate in any training. However, only 18.1% and 27% of the MHH and FHHs have participated in training during the previous year respectively. Consequently, 79.2% of the Non-PSNP did not participate in training, while only 20.8% of them did participate. The level of participation of the Non-PSNP households is slightly better than the PSNP households, though the level of training participation is very low for both groups. Generally, 82.3% of the sampled households did not participate in training while 17.7% did participate. However, the level of MHHs' and FHHs' participation in training for the whole sample is similar.

The results indicated that the field day participation of the sampled households was only 2.8% for MHH PSNP households while 3.7% for Non-PNSP FHHs (Table 14). Generally, only 3.3% of PSNP did participate in field days which are very small level of participation. The level of participation for Non-PSNP also revealed that there is no MHHs participation while 5.4% of the FHHs did

Table 14
Extension services participation by the Households disaggregated by PSNP status.

Extension service	Response	PSNP				Non-PSNP				Chi2
		MHH		FHH		MHH		FHH		
		Freq	%	Freq	%	Freq	%	Freq	%	
Training	No	60	83.3	92	85.2	68	81.9	27	73.0	1.3788
	Yes	12	16.7	16	14.8	15	18.1	10	27.0	
Field days	No	70	97.2	104	96.3	83	100	35	94.6	0.7705
	Yes	2	2.8	4	3.7	0	0	2	5.4	
Exchange visit	No	67	93.1	101	93.5	75	90.4	33	89.2	1.0870
	Yes	5	6.9	7	6.5	8	9.6	4	10.8	
Access to market information	No	43	59.7	68	63.0	41	49.4	21	56.8	2.9493*
	Yes	29	40.3	40	37.0	42	50.6	16	43.2	
Demonstration	No	71	98.6	107	99.1	83	100.0	35	94.6	0.1689
	Yes	1	1.4	1	0.9	0	0.0	2	5.4	

Source: Own survey (2018)

participate at field days. Generally, 97.3% of the sampled households did not participate in field days. However, only 2.7% did participate in field days.

In addition to field day participation, exchange visit is also another important extension method that is helpful to create awareness on innovations and practices. The level of participation in exchange visits of the MHH and FHH PSNP households was similar, which is less than 7%, while for the Non-PSNP is near to 10% for the MHHs and 11% for the FHHs.

The access to market information showed that the percentage of PSNP MHH and FHHs was almost similar which is 40% and 37%. However, 50% of the Non-PSNP MHHs had access to market information while about 43% of the FHH Non-PSNP households had access but the remaining did not as indicate in Table 15. As the level of participation is low, significant difference is not observed for the MHH and FHHs as indicated in Table 15.

Few women had access to training in the extension system. Thus, from the total female who have access to different trainings 50% of the PSNP MHH females have got training on nutrition, 33.3% on agronomy, and 16.7% on health. The figure for the NPSP females showed that 43.8%, 35.2%) and 25% have got training on agronomy, nutrition and health respectively. Generally, 43%, 39%, 21.4% and 6.7% of the PSNP households have got training on nutrition, agronomy, health and animal husbandry respectively as Indicated in Table 16.

The female in Non-PSNP MHH had access to training on nutrition, health and agronomy and accounts for 86.7%, 20% and 6.7% respectively. While the figure for the FHH showed that 50%, 20% and 20% had access to training on agronomy, nutrition and health respectively. Generally, 60%, 24% and 20% of the Non-PSNP households have got training on nutrition, agronomy and health respectively and one on animal husbandry. Association between the PSNP status of the households and the type of training is observed.

Contact with extension agents is a proxy for access to extension services. The results showed that the frequency of the sampled households being visited by the extension service was very low. For example, 44 %, 67.6%, 47% and 59% of the sampled MHH and FHH PSNP and Non-PSNP households were never visited by extension agents or they were being visited once in a year which is very limited as indicated in Table 17. Though the frequency of farmers visited were low, most of the respondents replied that the information provided by the extension agents was useful and or neutral as indicated in Table 17.

4.6. Access to improved varieties

Access to improved agricultural practices and improved varieties have strong association with improvement in livelihood outcomes like food security, income, productivity and asset. Our findings reveal that the adoption level of the sampled households showed that 25.2% and 16.1% of the plots of the MHH and FHH PSNP household had adopted improved varieties, totally 20.2% of the PSNP had adopted improved varieties at their plots (Table 18). While, 24.8% and 13.1% of the MHH and FHHs Non-PSNP households plot did adopt improved varieties respectively. The total plots covered by the Non-PSNP that adopted improved varieties were 21.5%. The implication is that the adoption level of at least one type of improved varieties at their plots was very low which is 20.8%. The inferential statistics reveals that there is strong association in adoption of improved varieties and PSNP status of the male and female-headed households.

Most of the farmers that have adopted wheat varieties is due to the varietal options. About 91% of the wheat variety adopter farmers have explained many reasons. The first reason was higher yield followed by promotion made by the government. Furthermore, neighbors', experience of growing the varieties and its suitability to the agro-ecology were also mentioned. The results further revealed that improved variety of food barley, potato and tomato were cultivated by only few farmers.

The main reason to adopt these improved varieties was market considerations for both PSNP and Non-PSNP households as indicated in Table 19. The varieties are demanded by the traders. The second reason why the Non-PSNP households decided to adopt was due to higher yields of the improved varieties than the local ones, while for the PSNP, the varieties were promoted by the government like research centers and development experts. The government was pushing the PSNP to use these improved varieties due to the fact that pushy extension system was practiced for a long period of time than the pull system so that the wider adoption can be speedup willingly than pushing them to adopt the varieties.

Table 15
Extension services participation by the Households disaggregated by gender.

Extension service	Response	Gender						Chi2
		MHH		FHH		Total		
		Freq	%	Freq	%	Freq	%	
Training	No	128	82.6	119	82.1	247	82.3	0.0135
	Yes	27	17.4	26	17.9	53	17.7	
Field days	No	153	98.7	139	95.9	292	97.3	2.3405
	Yes	2	1.3	6	4.1	8	2.7	
Exchange visit	No	142	91.61	134	92.41	276	92.00	0.0653
	Yes	13	8.39	11	7.59	24	8.00	
Access to market information	No	84	54.19	89	61.38	173	57.67	1.5846
	Yes	71	45.81	56	38.62	127	42.33	
Demonstration	No	154	99.35	142	97.93	296	98.67	1.1544
	Yes	1	0.65	3	2.07	4	1.33	

Source: Own survey (2018)

Table 16
Types training farmers took.

Training Topic	PSNP				Non-PSNP				Chi2
	MHH		FHH		MHH		FHH		
	Count	%	Count	%	Count	%	Count	%	
Agronomy	4	33.3	7	43.8	1	6.7	5	50.0	12.1224**
animal husbandry	1	8.3	0	0.0	0	0.0	1	10.0	
Natural resources	0	0.0	0	0.0	0	0.0	0	0.0	
Nutrition	6	50.0	6	37.5	13	86.7	2	20.0	
Health	2	16.7	4	25.0	3	20.0	2	20.0	

Source: Own survey (2018)

Table 17
Frequency of extension agents visits and relevance of the information provided by DAs.

Particularities	Response	PSNP				Non-PSNP				Chi2
		MHH		FHH		MHH		FHH		
		Count	%	Count	%	Count	%	Count	%	
How often are you visited by the extension agent	Never	32	44.4	73	67.6	39	47.0	22	59.5	14.1116
	Once a year	39	54.2	31	28.7	40	48.2	13	35.1	***
	Every month	1	1.4	4	3.70	4	4.8	1	2.7	
	Every two weeks	0	0.0	0	0.0	0	0.0	1	2.7	
	Weekly	0	0.0	0	0.0	0	0.0	0	0.0	
How do you assess the information provided by the extension agent	Very useful	8	11.1	11	10.2	10	12.0	7	18.9	3.9060
	Useful	39	54.2	41	38.0	43	51.8	18	48.6	
	Neutral	22	30.6	49	45.4	28	33.7	11	29.7	
	Not useful	3	4.2	7	6.5	2	2.40	1	2.7	
	Very un-useful	0	0.0	0	0.00	0	0.00	0	0.0	

Source: Own survey (2018)

Table 18
Adoption level of improved varieties by the sampled households.

Variety type	PSNP				Non-PSNP				Total				Chi2
	MHH		FHH		MHH		FHH		MHH		FHH		
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	
Improved	32	25.2	25	16.1	38	24.8	8	13.1	70	25	33	15.3	7.0048
Local	95	74.8	130	83.9	115	75.2	53	86.9	210	75	183	84.7	***

Table 19
Reasons for adoption of improved varieties.

Decision to adopt	PSNP		Non-PSNP	
	Count	%	Count	%
Higher yields	9	15.5	11	22.4
Market considerations/Promotion	23	39.7	17	34.7
No other varieties available	0	0.0	1	2.0
Promoted by neighbors	4	6.9	3	6.1
Promoted by government	11	19.0	8	16.3
Tradition of growing this variety	1	1.7	0	0.0
Variety is suitable for farm conditions	8	13.8	6	12.2
Cannot afford other available varieties	0	0.0	0	0.0
Do not know of any other varieties	1	1.7	0	0.0
Does not know	0	0.0	0	0.0
Not applicable	1	1.7	3	6.1

Source: Own survey (2018)

The third major reason why the Non-PSNP farmers used improved varieties was also due to varietal promotion activities done by the government with model farmers while for the PSNP was due to higher yields obtained from the improved varieties. Another reason includes that the varieties were suitable to the agro-ecologies, their tolerance to disease and adoption of these varieties by their neighbors and peers.

The low productivity of agriculture also contributed to food insecurity and poverty, and it is attributed to biophysical constraints and the underdeveloped state of the seed sector. There is strong historical evidence indicating that improved cultivars and the seed systems required to deliver farmer preferred cultivars to smallholders are highly effective pathway to enhance agricultural productivity and improving food security. Crop production and productivity is highly dependent of the quality of inputs like seeds. The quality of seed is also dependent on the seed sources and availability of input providers.

The results revealed that seed sources of the sampled households for the PSNP households was informal which accounts 53% followed by the own seed from previous harvest which nearly constitute about 35% (Table 20). The seed acquired from the intermediary and formal one is very low. However, the largest sources for the Non-PSNP was home saved 51% followed by informal 40%. The formal and intermediary sources accounts very small share which is less than 10%. Generally, the sources of seeds were informal 47.4% and home saved 41.8% for the whole sample. The intermediary accounts for 6.6 % and the formal was 4.2%.

The seeds were acquired by purchasing or buying accounts for 56.3% followed by saved from own stocks 41.1% for the PSNP households. While for the Non-PSNP the reverse holds true and about 52.7% and 46% of them acquired seed from saved own stocks and purchase respectively. Little amount was obtained as a free gift from different sources. The findings reveal that 90% the seed sector is dominated by informal seed system with limited share of intermediary and formal seed systems which accounts for 10%.

5. Discussion

5.1. Socio-economic status, gender differences, asset ownership of the households

The socio-economic status of the households did not vary due to being PSNP or Non-PSNP; the two groups have almost similarity except that the Non-PSNP households have slightly higher family size. However, the land ownership shows clear difference among the two groups. The female headed households shared out almost all the land, which has a clear implication to lower their food and nutrition security status, crops diversification and intensification is lower in shared out lands than their own plots. The female headed households shared out their land due to their incapability to plough it. On the other hand, the male headed households shared in land to overcome land shortages. Further, the landholding status of the PSNP and Non-PSNP disaggregated by gender showed significant difference. The implication is that there is large inter and intra variation in land holding with being MHH, FHH, PSNP and Non-PSNP status [37]. also pointed out that fragmented and decline in land holding of millions small-scale subsistence farmers with less than 1 ha, produce food crops in extremely challenging conditions that resulted in very low yields and food insecurity. To alleviate the land shortage, agricultural intensification is important. Further, interventions like high value crops are imperative so that the income with low level of land-holding can be enhanced and help them to purchase from the market consumable goods that are necessary for food and nutrition security.

The household gender is significantly related with being PSNP beneficiaries and Non-PSNP households. There is clear and significant difference in total area of land shared, and it is almost more than double for the Non-PSNP households than their PSNP counter parts. The potential reason may be due to the availability of resources and capacity to operate more land among the Non-PSNP households than the PSNP households which have fewer resources endowment like draft animals, capacity to hire labour and financial capability to purchase necessary agricultural inputs like seeds, fertilizer and other inputs. The implication is that enhancing the capacity of PSNP households would increase the households' capacity to operate more land which has a direct implication for food production thereby ensuring food security. For example, creating access and use of high yielding improved varieties with its packages to PSNP households may help them in producing more from their available land so that their food production capacity would enhance

Table 20
Seed sources and acquisition of the households.

Type of seed source	PSNPP		Non-PSNP		Total	
	Count	%	Count	%	Count	%
Home saved (Seed saved from previous season)	131	34.9	140	51.1	271	41.8
Informal (Friends/neighbour/relatives, local market)	199	53.1	109	39.8	308	47.4
Intermediary (Agent, MPCs, NGOs, CBSGs)	24	6.4	19	7	43	6.6
Formal (Government, Agro input dealer, …)	21	5.6	6	2.2	27	4.2
Seed acquired						
Saved from my own stocks	154	41.1	144	52.7	298	46.0
Exchange/barter	1	0.3	2	0.7	3	0.5
Gift (friend/relatives/neighbors)	7	1.9	2	0.7	9	1.4
purchase/buy	211	56.3	126	46.2	337	52.0
Vouchers	0	0.0	1	0.4	1	0.2
Seed loan	4	1.1	2	0.7	6	0.9
Food aid	0	0.0	1	0.4	1	0.2

Source: Own survey (2018)

food security and reduce their aid dependency. In this regard, empirical evidences obtained in different countries also revealed similar results that improved agricultural technologies adoption play an important role in improving agricultural productivity, economic growth, and facilitate the transition from subsistence agriculture to market-oriented agriculture [134–138].

There was a significant and clear difference in educational status among the PSNP and Non-PSNP households. This implies special attention during intervention in producing extension materials and capacity building activities which consider the education status of target households. Thus, practical training, graphical and pictorial extension education are more applicable than written extension materials for innovations and best fit practices promotion. The implication is while designing interventions, the need of both groups should be differentiated and intervention should be made based on their interest. This finding is in line with [139] that found enhancing community-based nutrition education is important in improving nutrition of the households.

Our findings revealed that high and significant difference in asset ownership were observed among the PSNP and NPSP households. This implies that intervention that improves the asset ownership of the households needs to be targeted at larger scale to fill the gap between the two groups. The 2018 midterm evaluation of PSNP 4 indicated that the mean TLU for Tigray was 1.8, and it was the lowest from the other regions. But in our finding, the TLU for PSNP was below the midterm evaluation while greater for the whole sample. To enhance the asset ownership, interventions that improve the income of the households are highly important. For example, research and development activities on poultry and small ruminants could directly contribute to build asset of the households, and other interventions that increase production and productivity of the households may also contribute to enhance the purchasing power of the households due to enhanced income indirectly.

In general, the Non-PSNP households have better asset ownership than the PSNP beneficiaries with clear and significant statistical difference. Asset and income are a proxy measures for poverty. Therefore, the result can be taken as a benchmark to improve the asset index of the households directly and reduce poverty indirectly for both PSNP and FHHs.

5.2. Food and nutrition status and intensity of the households

The results further showed that the respondents suffer from inadequate food availability in the months of August, September, July, June and October respectively. The availability of food depends on the period of new harvest of crops. The implication is that during the adequate period for food, awareness must be created to save their grains from extravagance expenditure to sustain consumption for the food shortage months that start in May and starts to ease in November due to new harvests.

There is a clear and significant difference in DDS for male headed households in relation to PSNP participation status. The Non-PSNP female headed households have better dietary diversity than FHH PSNP households. The results further showed that the DDS of the PSNP is lower than the Non-PSNP counterparts. The Non-PSNP are better off than the PSNP households in terms of dietary diversity in Tigray Region. The results further reveal that the food gap months of the PSNP households is by far higher than the Non-PSNP. Thus, bridging the food gap by reducing the food gap months will be the major focus for interventions. Studies pointed out that small-scale homestead production of micronutrient-rich foods, when combined with nutrition education, can have a greater impact on household income and nutrition. This contributes to increasing the frequency of eating vegetable and fruit product and taking the home garden as a source of income to fulfil the food gaps especially to buy different food stuff from the market which supports the household to consume more vegetable and improves the health status of the household especially to poor households [56].

The mean comparison of the food gap months of the Non-PSNP households is significantly lower than the PSNP counter-parts and the food gap months of the male headed households is by far lower than the male headed counter-parts. The Non-PSNP and male-headed households are better off than the PSNP households in terms of HDDS and lower average food gap months. This can give a clear insight to set targets for both PSNP and FHHs in development projects that focus in areas of food and nutrition security. Nutrition-sensitive interventions such as homestead production of diverse, nutrient-rich foods, coupled with behaviour change communication, may have positive effects on the nutritional status and health of rural households engaged in agriculture, particularly among women and young children. [140], indicated that harmonizing of agriculture and health extension workers may be an effective way of delivering nutrition-sensitive interventions given the dearth of trained health care providers in many developing countries.

There is similarity in food groups consumed by the PSNP and Non-PSNP households. Both PSNP and Non-PSNP households depends on cereals based staple food for consumption. However, the consumption of root and tuber crops food items is very low for both PSNP and Non-PSNP households. The consumption of vegetables is better than root and tubers. However, fruits consumption is by far less than that of vegetables. This implies that emphasis should be given to fruit production to enhance the dietary diversity of households for the future. This finding is in line with [57,141] which pointed out that low intake of fruits and vegetables is a major cause of micronutrient deficiencies in the developing countries. The consumption of pulses and oil crops is also similar with high consumption level in different forms of food items. There is no fish consumption in the study areas.

The findings also indicated that very low level of any meat and meat products consumptions within 24 h of the interview period. The same is true for egg, milk and milk products consumption. The implication is that intervention in poultry and small ruminants in particular and livestock in general may enhance the dietary diversity of the households. Hence, enhancing production and productivity of PSNP by adopting best fit practices and creating access to improved and farmer preferred seeds may build the assets of PSNP may stimulate livestock purchase that further translate to nutrition as the result of dietary diversity. Construction of micro-dams and irrigation schemes may enhance fish production and household members may consume fish and enhance the DDS. The scales of the intensity of HDDS shows considerable proportion of sample households that fall under medium household dietary diversity score which means the households and their family members consume 4 to 6 food groups. The HDDS for Non-PSNP was highly significantly differs than the PSNP households which shows the Non-PSNP households are better off then their counterparts. The Non-PSNP households consume more food groups than the PSNP counterparts as their socio-economic status is better than the PSNP. The

gendered difference in HDDS also revealed similar results. The HDDS for the PSNP male headed households lower than the Non-PSNP counter parts. Similarly, the HDDS for female headed households revealed that the PSNP female headed households have low HDDS than the Non-PSNP which is highly significant. The male average HDDS was better than the female headed households as the female headed households are more vulnerable than the male counterparts. Empirical evidences in Ethiopia showed that with increased in poultry production egg consumption by children increased [139,142] showed that owning cow has the potential to reduce stunting levels and positive associations between livestock ownership and anthropometric measures were also documented by Refs. [143,144].

5.3. Shocks and resilience of the households

Shocks and hazards like drought and erratic rainfall are the most common hazards faced by both PSNP and Non-PSNP households. However, the numbers of FHH in PSNP have the largest proportion in reporting drought. This is because the problem is aggravated due to their low potential to practice their farming activities during the on-set of the rainfall even to harness the opportunity that they can make use of on time farming to escape its negative effects. The impacts of these shocks and hazards have multiple extraneous effects on the livelihoods of the households. The most important impact was loss of crops and yield reduction due to the effects of these shocks [145]. also pointed out that unreliable rainfall patterns, droughts, floods, extreme temperatures resulting from effects of climate change are creating serious challenges to food production. Weather variability has an adverse impact on food security of the households [146–148]. Hence, to reduce the effects of erratic rainfall distribution, planting drought tolerant and early maturing varieties, promoting water harvesting techniques, ridging and soil and water conservation activities are important.

[82,149] clearly showed the importance of adoption and adaptation to climate change effects. Using appropriate soil and water diversions would also help to reduce the effect of run-off. Hence, to reduce the impacts, the farmers especially the FHH PSNP households used to search for loan and borrow from different sources to feed their household members. This causes financial insecurity due to the fact that borrowing for food is not productive.

To cope up the shocks and hazards, the farmers have adopted different strategies indicating that the reactive coping strategies are more common than the proactive ones. These strategies include selling livestock, selling reserved seeds, loan and borrowing and remittance. This implies the farmers are depleting their livestock assets to cope the risks and shocks. Diversifying economic activities (crops, income, assets or savings) is mentioned as an important risk management and consumption smoothing strategy adopted by rural households [25,29,150]. Therefore, we would like to suggest that pro-active adaptation measures like increasing uptake of improved seeds resistant to drought and other management practices such as moisture conservation needs to be promoted in the study areas to reduce the effect of shocks. Thus, by doing so the asset depletion of the households would decrease directly and the resilience of the farmers to with-stand risks and shocks would be also enhanced.

Hence, activities on enhancing the adaptive capacity of the farmers thereby providing different types of improved seeds and conducting participatory research giving emphasis to the PSNP community may reduce the challenge [151,152]. found that participatory approaches are important in selecting traits that meet local needs and its role in improving food security in marginal environments. Consequently, it increases production and productivity which have a direct relation with food security especially for PSNP households which face chronic problem of access to improved seeds. Similar findings show that improved seeds are an important factor to agricultural development in the context of increasing population [28,153]

The farmers were also used collecting firewood and making charcoal for money to sustain life during shocks which in fact causes environmental degradation. Hence, sustainable use of and alternatives for charcoaling may help the farmers to make permanent business for their living in collaboration with PSNP Programme in areas selected for rehabilitation. Moreover, provision of farmers preferred varieties and seeds that are adaptable to the agro-ecologies is also an important entry points for intervention to enhance the adaptive capacity of the farmers to the hazards and stressors.

The reactive strategies adapted to cope the risks were by far higher than the pro-active ones. Thus, works on adaptive measures like water harvesting, using high yielding varieties, producing twice a year and the like are limited. Therefore, focusing on activities that contribute to the pro-active measure should be introduced and promoted to minimize the risks of the households especially for the vulnerable groups.

5.4. Agricultural practices and varietal diversification of the households

The productivity of all crops was quite below the regional and national averages. The potential reason may be due to the regional aggregate includes high potential areas while our study was focused on PSNP areas which are drought prone and low potential in terms of agricultural production. In fact, the low productivity is attributed due biotic and abiotic factors in the study areas. Low adoption rate also contributes to low level of productivity. The varietal portfolio is low and varietal diversification is important. Thus, we believe that mobilizing resources is important to fill the yield gap at all levels to enhance production and productivity [153]. also indicated increasing access to improved seeds appears a promising pathway for rural development.

Further, a clear productivity difference was observed among the MHH and FHH PSNP and Non-PSNP households for major crops. In most cases, the productivity of crops of the Non-PSNP households and MHHs are better than the PSNP and FHHs. Hence, the lower productivity is attributed to higher food gap months of the PSNP and FHHs. In addition, this result shows significant contribution to design policy and strategies in low potential areas and marginalized households' productivity.

5.5. Acesss to agricultural extension services of the households

Agricultural service plays an important role in facilitating linkages among input suppliers and end users, creating market linkage, research and extension linkages and consulting farmers in farming practices This implies that farmers' participation in extension services can improve the food security status of smallholder farmers. The level of participation of the Non-PSNP households is slightly better than the PSNP households, though the level of training participation is very low for both groups.

Generally, the level of participation in the exchange visits is very low for both groups. However, the level of participation in demonstration activities is worst. Though statistical difference was not observed for the level of participation in extension services like training, field days, exchange visits, demonstration and access to market information, the level of participation in extension services was very limited for all groups.

5.6. Seed system, and acesss to improved varieties of the households

The findings revealed that the seed sector is dominated by informal seed system. The implication is that strengthening the informal seed system can help smallholder farmers to have access to improved varieties. For example, approaches like crowdsourcing, on-farm trials and farmers' participation during varietal selection and participation could enhance diffusion of improved varieties in one hand and strengthening the formal seed system can also help the farmers to have access to quality seeds in the other hand [152,153]. also recommended farmers' participation to harness the benefits and selection of genetic resources and indigenous knowledges.

In general, the findings indicated that clear difference exists between PSNP households and Non-PSNP households in socio-economics status, productivity, market participation, use of inputs, adoption level food, and exposure and nutrition status. Therefore, we would like to point out that the results could serve as a benchmark and entry point for policy making, planning, and intervention for different actors at regional level. Goal level outcomes or impacts on enhanced human, organisational and institutional capacities to adapt, validate and scale best fit practices to improve the resilience of the different groups at regional and community level and can be crafted for the different groups (MHH, FHH, PSNP, Non-PSNP etc. Thus, interventions that focus at developing best fit practices that meet expressed needs and have the potential to contribute to increased productivity and resilience, seed access using different seed systems, building human, organizational and institutional capacities and creating conducive environment for the institutionalization of evidence-based system innovations can be taken as departure for planners, researchers, development organizations and others.

In summary, outcomes and targets can be therefore set at regional level at the PSNP woredas. For example, goal level outcomes can be to close the food gap months for the first terciles to zero and drop from 1.61 to 0.09 months for the second and from 3.13 to 1.61 for the 3rd terciles from 3.13 (99 days) months to some level can be targeted for all groups. For PSNP, close the food gap months zero by terciles, drop at most to 0.58 (17.4 days) months for the second terciles and 2.3 (69 days) months for the third terciles can be the target. Besides, to increase in Dietary Diversity Score of the PSNP, at regional level, FHHs from the current by desired food groups; Contribute to asset building or prevent asset depletion so that smallholder farmers do not have to lose their assets in order to smoothen consumption, and have improved food production using new capacity and improved capacities to deal with shocks and stressors to secure food production (shifting from reactive and proactive coping strategies) to report and demonstrate significant increase in resilience of the communities etc.

Aid and support on the major food gap months of August, September, July, October and June can be arranged to minimize hunger. Further, creating attitudinal change to reduce extravagance in the major food available months is also critical. Furthermore, supporting farmers in providing high yielding adaptable varieties and best fit practices that increase production and productivity would help to reduce the food gap months. Support in research and development that develops and disseminate appropriate technologies to help farmers to lower their food gap months is imperative.

Regarding resources, poor farmers by participating in best fit practices and improved varieties adoption can improve their wealth and productive resources ownership. To improve nutrition status of the households (increased DDS) engaging and promoting activities like nutrition sensitive agriculture (planting fruits, roots and tubers) and livestock (small ruminants and poultry) can be entry points. This can be done by exerting efforts to move the low and medium HDDS to high thereby focusing on the above food groups.

The major hazards and shocks faced by the households were drought, erratic rainfall and flooding for PSNP and Non-PSNP households especially for FHH PSNP households. The impact of these shocks and hazards has multiple extraneous effects on the livelihoods of the households. Hence, research and development intervention in providing different types of high yielding, disease resistant improved seeds, promoting water harvesting techniques, ridging and soil and water conservation activities that improve the absorptive and adaptive capacities to face the shocks and risks and taking reactive measures should be planned. Thus, technologies and innovations (improved varieties, fertilizer and farm chemicals) that improve productivity that withstand the negative impacts of biotic and abiotic factors could be validated, promoted and pre-scaled in Tigray.

Sustainable agricultural practices (water harvesting, crop protection, crop rotation and other agronomic practices like cropping pattern, system, and intensifications) could be research priority areas. Extension services like participating in training, field days, field visits and exchange visits were limited. This had a direct effect on production and productivity thereby reducing the management practices of the farmers on improved management and new technologies uptake. In general, planning on creating awareness on innovations and practicing improved agronomic practices, improved crop varieties and livestock breeds, and promotion of best fit practices and innovations for improved productivity and building resilience of the farming communities could be targeted. Increasing the varietal portfolio via diversified channels, creating and strengthening linkages in the seed systems, creating access to inputs, and participatory varietal selections could be planned.

6. Conclusions and recommendations

6.1. Conclusion

Food and nutrition security is a global development agenda, as the number of people who are food and nutrition insecure population grows over time especially in developing countries. In Tigray food and nutrition insecurity still remained among the major development challenges and the current incidence of poverty is high. Thus, the nutrition and health indicators reveal the prevalence of high level of food and nutrition insecurity in the region. The study has made a genuine effort to assess the socio-economic differences for PSNP and Non-PSNP, MHHs and FHHs, the status of food and nutrition security, resilience and access to practices and extension services differentiated by gender using appropriate methodologies. Thus, the data were collected from three food insecure woredas in Tigray and 300 randomly selected households proportional to size disaggregated by gender. The food gap months, and HDDS were used as a proxy measure to food and nutrition insecurity. Inferential statistics were used to draw conclusions from the findings.

The socio-economic status of the households varies significantly due to being PSNP or Non-PSNP and male and female headed households in ownership of productive resources. Ownership of resources like land, and asset ownership makes them vulnerable due to fewer resources endowment like draft animals, capacity to hire labour and financial capability to purchase necessary agricultural inputs like seeds, fertilizer and other inputs. This in turn contributed to lower households' food and nutrition security status as this limits crops diversification and intensification production and productivity. Similarly, significant and clear differences in household education status were observed among the PSNP and Non-PSNP households, implying that special attention should be paid during intervention in producing extension materials and capacity building activities that consider the education status of target households. In summary, the non-PSNP and male headed households have better productive resources than PSNP and female headed households.

The results further showed that the respondents face inadequate food availability in the months of August, September, July, June and October. Furthermore, there is a clear significant difference in DDS for gendered differences and being PSNP. Thus, Non-PSNP female headed households are better off in terms of dietary diversity than the FHH PSNP households. The results further showed that the PSNP has a lower DDS than their non-PSNP counterparts, and the Non-PSNP are better off than the PSNP households in terms of dietary diversity in the study areas. Similarly, the PSNP households have significantly longer food gaps than Non-PSNP households, and PSNP male headed households than the male headed counter-parts.PSNP and female-headed households consume fewer different food groups than Non-PSNP and male headed households counterparts. In summary, households and household members consume low amount of vegetables, fruit, eggs, milk, meat and meat products.

Shocks and hazards like drought and erratic rainfall are the top ranked common hazards faced by both PSNP and Non-PSNP households especially female headed households who are in PSNP have the largest proportion in reporting drought. To adapt the effects of climate change and weather variabilities, households employed soil and water conservation techniques, search for loan and borrow from different sources to feed their household members, selling livestock, selling reserved seeds, loan and borrowing and remittance. Besides, the farmers were also used collecting firewood and making charcoal for money in order to sustain life during shocks which in fact causes environmental degradation.

The productivity of all crops was quite below the regional and national averages. Furthermore, there was a clear productivity difference among the MHH and FHH PSNP and Non-PSNP households for major crops. In most cases, Non-PSNP households and MHHs had higher crop productivity than the PSNP and FHHs. The level of participation in extension services of the Non-PSNP households is slightly better than the PSNP households. The findings revealed that the seed sector is dominated by informal seed system, PSNP and female headed households have lower varietal diversification compared to the Non-PSNP and male headed households counterparts.

In summary, the findings indicated that clear difference exists between PSNP households and Non-PSNP households in socio-economics status, productivity, market participation, use of inputs, adoption level food, and exposure and nutrition status. Therefore, the results could serve as a benchmark and entry point for policy making, planning, and intervention for different actors to set goal level outcomes or impacts on enhanced human, organisational and institutional capacities to adapt, validate and scale best fit practices to improve the resilience of the different groups at regional and community level and can be crafted for the different groups (MHH, FHH, PSNP, Non-PSNP etc.).

6.2. Recommendations

As indicated above, there are clear and significant differences in socio-economic status, food and nutrition security, resilience to shocks and hazards, and access to extension services and seed systems among PSNP, Non-PSNP, and gender. Cognizant of these facts, the findings would enable actors to craft appropriate intervention measures to fill the food gap months and enhance DDS, thereby building their assets and increasing production and productivity levels. To solve these problems, practical training, conducting farmer's participatory research, and field days are more applicable than written extension materials for promoting innovations and best fit practices. The food gap months could be also reduced by introducing and promoting high yielding improved varieties and management practices available in the research and extension consortium. Supporting farmers in providing high yielding adaptable varieties and best fit practices that increase production and productivity would help to reduce the food gap months. Support for research and development that develops and disseminates appropriate technologies to help farmers to lower their food gap months is imperative. Enhancing production and productivity of PSNP by adopting best fit practices and creating access to improved and farmer preferred seeds may build the assets of PSNP so that they may purchase livestock that further translate into increased DDS indirectly. Moreover, synergy and collaboration with other stakeholders, like Bureau of Agriculture, nearby Agricultural Research centers, NGOs and other development actors may help to achieve the target. Intervention that focused on sustainable intensification, off-farm

employment alternatives, and engaging in agribusiness activities that help to create livelihood options for resource poor farm households is important. To solve the low productivity levels of the major crops, not only improved varieties, but also promoting sustainable agricultural practices should also be given focus to enhance production and productivity in the study areas. Following participatory approach in activities like crowd sourcing would help to fasten the dissemination of farmers' preferred varieties and may change the top down extension system. Moreover, strengthening the formal seed system would also help farmers to access quality seeds. During the introduction of new farmers' preferred varieties that have been adapted to the agro-ecologies through validation, demonstration and pre-scaling practical training is needed at ground level. Appropriate extension services should be given to farmers both temporally and spatially during promotion of best fit practices and innovations to improve productivity and building resilience of the farming communities.

Funding

Please add: "This research was funded by Wageningen University and Research (WUR).

Institutional review board statement

"Not applicable" for studies not involving humans or animals.

Data availability statement

"The authors confirm that the data supporting the findings of this study are available on request from the corresponding author".

CRediT authorship contribution statement

Afeworki Hagos Mesfin: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Kidane Giday:** Gebremedhin, Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Conceptualization. **Tewodros Tefera:** Writing – review & editing, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Mulugeta Diro Chimsa:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition. **Remko Vonk:** Writing – review & editing, Resources, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Afeworki H. Mesfin reports financial support was provided by Wageningen University and Research. Afewrorki reports a relationship with Non that includes: employment. Afeworki has patent No pending to No. There is no conflict of interests among the authors.

Acknowledgments

We would like to acknowledge the PMU staff for the facilitation and follow up during the baseline survey. The Woreda Office of Agriculture (WoA) staffs, food security experts and Development Agents (DAs) have also contributed a lot in providing the list of PSNP beneficiaries and Non-PSNP and their overall support during the field survey; without their keen support, the data collection process would have been impossible. Also, we appreciate the community facilitators in directing us during the survey time for their tireless journey to show us the doors of the randomly selected farmers. With ups and downs they have been in our side to help us. The development agents are appreciated for their participation in selecting the community facilitators to collect data. We deeply appreciate the farmers who volunteered their time and willingness for the interview and gave relevant information for the intended research. Finally, we acknowledge the enumerators for their special dedication during the entire data collection, which was accomplished based on schedule. Our special thank goes to Dr. Zenebe Abraha for his generous support, valuable suggestions and improvements by reviewing this paper. This paper is made possible by the generous and insightful support of the Dutch government and WUR; and we heartily thank and duly recognize their support and facilitation starting from questionnaire development and organizing workshops to enrich the results.

References

[1] M.D. Smith, W. Kassa, P. Winters, Assessing food insecurity in Latin America and the Caribbean using FAO's food insecurity experience scale, Food Pol. 71 (2017) 48–61.
[2] H.K. Seligman, R. Levi, V.O. Adebiyi, A. Coleman-Jensen, J.F. Guthrie, E.A. Frongillo, Assessing and monitoring nutrition security to promote healthy dietary intake and outcomes in the United States, Annu. Rev. Nutr. 43 (2023).
[3] US Dep, Food security in the U.S, Agric. Econ. Res. Serv. (2022). https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/.

[4] US Dep. Agric. Food Nutr. Serv, USDA Actions on Nutrition Security, Doc., US Dep. Agric., Washington, DC, 2022. https://www.usda.gov/sites/default/files/documents/usda-actions-nutrition-security.pdf.
[5] H. Pieters, A. Guariso, A. Vandeplas, Conceptual Framework for the Analysis of the Determinants of Food and Nutrition Security, 2013. No. 2201-2019-1442).
[6] N. Omidvar, D. Ahmadi, K. Sinclair, H. Melgar-Quiñonez, Food security in selected Middle East and North Africa (MENA) countries: an inter-country comparison, Food Secur. 11 (2019) 531–540, https://doi.org/10.1007/s12571-019-00935-w.
[7] World Health Organization, The State of Food Security and Nutrition in the World 2018: Building Climate Resilience for Food Security and Nutrition, Food & Agriculture Org., 2018.
[8] UNICEF, The State of Food Security and Nutrition in the World 2018 - UNICEF DATA, 2018.
[9] H.R. Dillard, Global food and nutrition security: from challenges to solutions, Food Secur. (2019) 1–4.
[10] T.A. Sisha, Household level food insecurity assessment: evidence from panel data, Ethiopia, Scientific African 7 (2020) (2020), https://doi.org/10.1016/j.sciaf.2019.e00262.
[11] MoANR, & MoLF, Nutrition Sensitive Agriculture Strategy, Ministry of Agriculture and Natural Resource (MoANR) and Ministry of Livestock and Fisheries (MoLF), Addis Ababa, Ethiopia, 2016.
[12] R. Jenkins, F. Baingana, R. Ahmad, D. McDaid, R. Atun, Mental health and the global agenda: core conceptual issues, Ment. Health Fam. Med. 8 (2) (2011) 69–82.
[13] S. McGuire, FAO, IFAD, and WFP. The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO, 2015, Adv. Nutr. 6 (5) (2015) 623–624.
[14] H. Tesfaye, T. Masresha, F. Mariama, L. Zelalem, Integrating Nutrition into Crop and Livestock Farming Systems of the Ethiopian Highlands for Improved Nutrition Outcomes (Training Manual), International Livestock Research Institute ILRI, 2016.
[15] F.C. Prospects, Food Situation—Quarterly Global Report No. 1, FAO, Rome, Italy, 2020, https://doi.org/10.4060/ca8032en.
[16] G. Ramakrishna, A. Demeke, An Empirical Analysis of Food Insecurity in Ethiopia: the Case of North Wello, Africa Development/Afrique et Développement, 2002, pp. 127–143.
[17] B. Endalew, M. Muche, S. Tadesse, Assessment of food security situation in Ethiopia, World J. Dairy Food Sci. 10 (1) (2015) 37–43.
[18] E. Demographic, Addis Ababa, Ethiopia, and Rockville, Maryland, MA, USA: CSA and ICF, 2016.
[19] EPHI, Ethiopian national micronutrient survey report, Addis Ababa: Ethiopian Public Health Institute (EPHI) (2016).
[20] K. Hirvonen, A.S. Taffesse, I. Worku, Seasonality and household diets in Ethiopia, Publ. Health Nutr. 19 (10) (2016) 1723–1730.
[21] K. Hirvonen, K. Headey, Can governments promote homestead gardening at scale? Evidence from Ethiopia, Global Food Secur. 19 (2018) (2018) 40–47, https://doi.org/10.1016/j.gfs.2018.09.001.
[22] K. Hirvonen, A. Wolle, Consumption, Production, Market Access and Affordability of Nutritious Foods in the Tigray Region of Ethiopia, Alive & Thrive and International Food Policy Research Institute, Addis Ababa, Ethiopia, 2019.
[23] L. Cochrane, Strengthening Food Security in Rural Ethiopia, Interdisciplinary Studies) submitted to the University of British Columbia, 2017. Doctoral Dissertation.
[24] R.J. Schwei, H. Tesfay, F. Asfaw, W. Jogo, H. Busse, Household food insecurity is associated with both body mass index and middle upper-arm circumference of mothers in northwest Ethiopia: a comparative study, Publ. Health Nutr. 20 (9) (2017) 1540–1547, https://doi.org/10.1017/S1368980017000350.
[25] S. Dercon, Growth and shocks: evidence from rural Ethiopia, J. Dev. Econ. 74 (2) (2004) 309–329.
[26] S. Di Falco, M. Bezabih, M. Yesuf, Seeds for livelihood: crop biodiversity and food production in Ethiopia, Ecol. Econ. 69 (8) (2010) 1695–1702.
[27] J. Gao, B.F. Mills, Weather shocks, coping strategies, and consumption dynamics in rural Ethiopia, World Dev. 101 (2018) 268–283. Asfaw, S. and Shiferaw, B. A., 2010. Agricultural technology adoption and rural poverty: Application of an endogenous switching regression for selected East African Countries (No. 308-2016-5081).Tesfaye, W.; Tirivayi, N. Crop diversity, household welfare and consumption smoothing under risk: Evidence from rural Uganda. World Development. (2020), 125:104686.
[28] S. Devereux, I. Sussex, Food Insecurity in Ethiopia, Institute for Development Studies, Brighton, UK, 2000, p. 7.
[29] A. Van der Veen, T. Gebrehiwot, Effect of policy interventions on food security in Tigray, Northern Ethiopia, Ecol. Soc. 16 (1) (2011).
[30] H. Afework, G. Kidane, L. Amanuel, T. Tewodros, D. Mulgeta, BENEFIT-REALISE Baseline Report, 2019 *(Unpublished report)*.
[31] M. Balehegn, M. Haile, C. Fu, W. Liang, Ecosystem-based adaptation in Tigray, northern Ethiopia: a systematic review of interventions, impacts, and challenges, in: W. Leal Filho (Ed.), Handbook of Climate Change Resilience, Springer, Cham, 2019.
[32] G. Gebremedhin, T.G. Gebremicael, G. Abbadi, Economic and environmental rehabilitation through soil and water conservation, the case of Tigray in northern Ethiopia, JAE 151 (2018) (2017) 113–124.
[33] UN (United Nations), The Sustainable Development Goals Report 2019, 2019. New York URL: https://unstats.un.org/sdgs.
[34] EDHS (Ethiopia Demographic and Health Survey) Key Indicators Report, 2016.
[35] S. Di Falco, J.P. Chavas, On crop biodiversity, risk exposure and food security in the highlands of Ethiopia, Am. J. Agric. Econ. 91 (3) (2009) 599–611.
[36] B. Davis, L. Lipper, P. Winters, Do not transform food systems on the backs of the rural poor, Food Secur. 14 (2022) 729–740, https://doi.org/10.1007/s12571-021-01214-3.
[37] S. Bezu, G.T. Kassie, B. Shiferaw, J. Ricker-Gilbert, Impact of improved maize adoption on welfare of farm households in Malawi: a panel data analysis, World Dev. 59 (2014) 120–131, https://doi.org/10.1016/j.worlddev.2014.01.023.
[38] L. Cochrane, P. Costolanski, Climate Change Vulnerability and Adaptability in an Urban Context: A Case Study of Addis Ababa, Ethiopia, 2013.
[39] C. Hadley, D.A. Linzer, B. Tefera, G.M. Abebe, T. Fasil, D. Lindstrom, Household capacities, vulnerabilities and food insecurity: shifts in food insecurity in urban and rural Ethiopia during the 2008 food crisis, Soc. Sci. Med. 73 (2011) 1534–1542.
[40] A.M. Teka, S.-K. Lee, The impact of agricultural package programs on farm productivity in Tigray-Ethiopia: panel data estimation, Cogent Economics & Finance 7 (1) (2019) 1631987, https://doi.org/10.1080/23322039.2019.1631987.
[41] A. Van Rompaey Teka, J. Poesen, Y. Welday, J. Deckers, Impact of climate change on small-holder farming: a case of eastern Tigray, northern Ethiopia, Afr. Crop Sci. J. 20 (2) (2012) 337–347.
[42] S.K. Weldearegay, D.G. Tedla, Impact of climate variability on household food availability in Tigray, Ethiopia, Agric & Food Secu 7 (6) (2018) 1–9, https://doi.org/10.1186/s40066-017-0154-0.
[43] T. Kelemework, Predicaments of rural development interventions in Tigray region, Ethiopia, J. Agric. Ext. Rural Dev. 4 (13) (2012) 365–371, https://doi.org/10.5897/JAERD11.152.
[44] M. Gebru, T.H. Stein, A. Frode, Adoption analysis of agricultural technologies in the semiarid northern Ethiopia: a panel data analysis, Agricultural and Food Economics 9 (2011) 12, https://doi.org/10.1186/s40100-021-00184-6.
[45] S. Wiggins, S. Keats, Smallholder Agriculture's Contribution to Better Nutrition, ODI, London, 2013.
[46] T. Hailu, M. Tessema, M.M. Fofanah, Z. Lema, Nutrition Training Manual for Health and Agriculture Workers at Community Level in Ethiopia: Integrating Nutrition into Crop and Livestock Farming Systems of the Ethiopian Highlands for Improved Nutrition Outcomes, 2016.
[47] FDRE (Federal Democratic Republic of Ethiopia), National Nutrition Strategy. Addis Ababa, Ethiopia, 2008.
[48] Food and Agriculture Organization, Second International Conference on Nutrition (NUTRITION-SENSITIVE AGRICULTURE), 2014.
[49] K. Hirvonen, D. Headey, Can governments promote homestead gardening at scale? Evidence from Ethiopia, Global Food Secur. 19 (2018) (2018) 40–47.
[50] A. Deaton, N. Cartwright, Understanding and misunderstanding randomized controlled trials. Social, Sci. Med. 210 (2018) 2–21, https://doi.org/10.1016/j.socscimed.2017.12.005.
[51] MoH, Ethiopian Ministry of Health, National Nutrition Strategies, 2008.
[52] GFDRE, National Nutrition Programme 2016–2020, Government of the Federal Democratic Republic of Ethiopia (GFDRE), Addis Ababa, 2016.
[53] J. Fanzo, C. Hawkes, K. Rosettie, Making SMARTer commitments to nutrition action: global nutrition report guidance note, Intl Food Policy Res Inst (2016).
[54] USIAD, Ethiopia Nutrition Profile, 2014.

[55] Ethiopia Demographic and Health Survey, Central Statistical Agency, Addis Ababa & ICF International, Calverton, MD, 2011.
[56] H. Kalle, H. Derek, Can governments promote homestead gardening at scale? Evidence from Ethiopia, (2018), Global Food Secur. 19 (2018) (2018) 40–47.
[57] D. Headey, N. Phuong, K. Sunny, R. Rahul, R. Marie, M. Purnima, Is exposure to animal feces harmful to child nutrition and health outcomes? A multicountry observational analysis, Am. J. Trop. Med. Hyg. 96 (4) (2017) 961–969.
[58] A. Mulugeta, G. Redae, H. Temesgen, M. Abay, Survey of under-five children malnutrition in urban and rural areas of Tigray region, Northern Ethiopia, Mekelle: Tigray statistical agency (2019).
[59] D. Mosha, C.R. Canavan, A.L. Bellows, et al., The impact of integrated nutrition-sensitive interventions on nutrition and health of children and women in rural Tanzania: study protocol for a cluster-randomized controlled trial, BMC Nutr 4 (2018) 29, https://doi.org/10.1186/s40795-018-0238-7.
[60] N.J. Haselow, A. Stormer, A. Pries, Evidence-based evolution of an integrated nutrition-focused agriculture approach to address the underlying determinants of stunting, Matern. Child Nutr. 12 (S1) (2016) 155–168.
[61] D.K. Olney, A. Pedehombga, M.T. Ruel, A. Dillon, A 2-year integrated agriculture and nutrition and health behavior change communication program targeted to women in Burkina Faso reduces anemia, wasting, and diarrhea in Children 3–12.9 months of age at baseline: a cluster-randomized controlled trial, J. Nutr. 145 (6) (2015) 1317–1324, https://doi.org/10.3945/jn.114.203539.
[62] J. Who, F.E. Consultation, Diet, nutrition and the prevention of chronic diseases, World Health Organ Tech Rep Ser 916 (i–viii) (2003) 1–149.
[63] Isaac, et al., Manual for Vegetable in Production Manual, 2006.
[64] J. von Braun, K. Afsana, L.O. Fresco, M.H.A. Hassan, Food systems: seven priorities to end hunger and protect the planet, in: Science and Innovations for Food Systems Transformation, Springer International Publishing, Cham, 2023, pp. 3–9.
[65] FAO, IFAD, UNICEF, WFP and WHO, The State of Food Security and Nutrition in the World 2021, FAO, Rome, 2021. http://www.fao.org/3/cb4474en/online/cb4474en.html.
[66] K. Sisay, M. Girma, Food and nutrition security status in Southwest region of Ethiopia: evidence from Kaffa zone, Journal of Agriculture and Food Research 14 (2023) 100717.
[67] UNICEF, Gender Toolkit: Integrating Gender in Programming for Every Child in South Asia, 2018.
[68] E.M. Yahia, M.E. Maldonado Celis, M. Svendsen, The contribution of fruit and vegetable consumption to human health. Fruit and Vegetable Phytochemicals: Chemistry and Human Health, second ed., 2017, pp. 1–52.
[69] E. Fao, ECA, Regional overview of food security and nutrition. addressing the threat from climate variability and extremes for food security and nutrition, Food and Agriculture Organization of the United Nations: 116, Accra (2018).
[70] FAO, The State of Food and Agriculture 1996, FAO, Rome, 1996.
[71] D. Mozaffarian, S. Fleischhacker, J.R. Andrés, Prioritizing nutrition security in the US, JAMA 325 (16) (2021) 1605–1606.
[72] S. Weiser, K. Palar, A. Hatcher, S. Young, E. Frongillo, B. Laraia, Food insecurity and health: a conceptual framework, in: L. Ivers (Ed.), Food Insecurity and Public Health, first ed., CRC Press, Boca Raton, FL, 2015, pp. 23–50.
[73] FAO, Food security, Policy Brief 2006 (2) (2006) (June).
[74] C.B. Barrett, E.C. Lentz, Food insecurity, in: The International Studies Compendium Project, Wiley-Blackwell Publishing, Oxford, UK, 2009.
[75] C.D. Deere, C.R. Doss, Gender and the distribution of wealth in developing countries, in: Working Paper RP2006/115. World Institute for Development Economic Research (UNU-WIDER). 2009. "Gender and Food Security." in Gender in Agriculture: Sourcebook, World Bank Publications, 2006. http://books.google.com/books?hl=en&lr=&id=XxBrq6hTs_UC&pgis=1.
[76] J. Hoddinott, Agriculture, health, and nutrition: toward conceptualizing the linkages, in: Reshaping Agriculture for Nutrition and Health, IFPRI, 2012.
[77] D. Atkin, The Caloric Costs of Culture: Evidence from Indian Migrants, National Bureau of Economic Research, 2013. Working paper 19196.
[78] J.A. Dohrmann, S. Thorat, Right to Food, Food Security and Discrimination in the Indian Context, 2007, pp. 9–31. *ASIEN* (January.
[79] R. Luo, Y. Shi, L. Zhang, H. Zhang, G. Miller, A. Medina, S. Rozelle, The limits of health and nutrition education: evidence from three randomized-controlled trials in rural China, CESifo Econ. Stud. 58 (2) (2012) 385–404. April 27.
[80] UN world Food Program, World Hunger Series 2007: Hunger and Health, Earthscan, 2007.
[81] M.T. Ruel, *Is Dietary Diversity An Indicator of Food Security or Dietary Quality?* FCND Discussion Paper 140, International Food Policy Research Institute (IFPRI), 2002.
[82] E. Gotor, M.A. Usman, M. Occelli, B. Fantahun, C. Fadda, Y.G. Kidane, D. Mengistu, A.Y. Kiros, J.N. Mohammed, M. Assefa, T. Woldesemayate, Wheat varietal diversification increases Ethiopian smallholders' food security: evidence from a participatory development initiative, Sustainability 13 (3) (2021) 1029.
[83] A. Quisumbing, R. Meizen-Dick, L. Bassett, Helping Women Respond to the Global Food Price Crisis, vol. 7, International Food Policy Research Institute. Policy Brief, 2008.
[84] K. Heitzmann, R.S. Canagarajah, P.B. Siegel, *Guidelines for Assessing the Sources of Risk and vulnerability* No. 0218. Social Protection Discussion Paper, World Bank, Washington, 2002.
[85] L. Alinovi, E. Mane, D. Romano, Towards the measurement of household resilience to food insecurity: applying a model to Palestinian household data, in: Deriving Food Security Information from National Household Budget Surveys. Experiences, Achievements, Challenges, FAO, Rome, 2008, pp. 137–152.
[86] B. Tefera, C. Hadley, D. Lindstrom, G. Abebe, W.M. Kifle, G. Yehenew, C. Lachat, P. Kolsteren, Gender differences in food insecurity and morbidity among adolescents in southwest Ethiopia, Pediatrics 127 (2011) e398–e405.
[87] B. Sosina, S. Holden, Are rural youth in Ethiopia abandoning agriculture? World Dev. 64 (2014) 259–272.
[88] C. O'Brien, N.S. Gunaratna, G. Kidist, Z.M. Gitonga, T. Mulunesh, H. de Groote, Gender as a cross-cutting issue in food security: the NuME Project and quality protein maize in Ethiopia, World Med. Health Pol. 8 (3) (2016) 263–286.
[89] L. Cochrane, Food security in Ethiopia: review of research, 2005-2016, Ethiop.J.Appl.Sci. Technol. 9 (1) (2018) 1–10.
[90] C. Hadley, D. Lindstrom, T. Fasil, B. Tefara, Gender bias in the food insecurity experience of Ethiopian adolescents, Soc. Sci. Med. 66 (2008) 427–438.
[91] B. Tibesigwa, M. Visser, Small-scale subsistence farming, food security, climate change and adaptation in South Africa: male-female headed house- holds and urban-rural nexus, Technical Report June, Economic Research Southern Africa (ERSA) (2015).
[92] J.A. Matz, M. Kalkuhl, G.A. Abegaz, The short-term impact of price shocks on food security-Evidence from urban and rural Ethiopia, Food Secur. 7 (2015) 657–679.
[93] S. Saravia-Matus, S.G.Y. Paloma, S. Mary, Economics of food security: selected issues, Bio-Based, Appl. Econ. 1 (1) (2012) 65–80.
[94] J. Nyssen, B. Govaerts, A. Tesfaye, W.M. Cornelis, H. Bauer, H. Mitiku, K. Sayre, J. Deckers, The use of the marasha ard plough for conservation agriculture in northern Ethiopia, in: E. Lifthouse, et al. (Eds.), Sustainable Agriculture, vol. 2, Springer, Cham, 2011.
[95] G. Sime, J.B. Aune, H. Mohammed, Agronomic and economic response of tillage and water conservation management in maize, central rift valley in Ethiopia, Soil Tillage Res. 148 (2015) 20–30.
[96] Falco S. Di, M. Veronesi, M. Yesuf, Does Adaptation to climate change provide Food security? A Micro-Perspective from Ethiopia, American Journal of Agricultural Economics Advance Access. JEL classification Q18 (2011) Q54.
[97] B.D. Abera, A. Keil, M. Zeller, Using panel data to estimate the effect of rainfall shocks on smallholders food security and vulnerability in rural Ethiopia, Climatic Change 108 (2011) 185–206.
[98] J. Abafita, K.-R. Kim, Determinants of household food security in rural Ethiopia: an empirical analysis, J. Rural Dev. 37 (2) (2014) 129–157. ISNN 1019-0341.
[99] S. Bhattarai Haddad, M. Immink, S. Kumar, Estimating the interactions between household food security and preschool diarrhea, Food Pol. 23 (3–4) (1998) 241–261.
[100] J. Mbukwa, A model for predicting food security status among households in developing countries, Int. J. Dev. Sustain. 2 (2) (2013) 544–555.
[101] H. Kidane, Z.G. Alemu, G. Kundhlande, Causes of household food insecurity in koredegaga peasant association, Oromiya zone, Ethiopia, Agrekon 44 (4) (2005) 543–560, https://doi.org/10.1080/03031853.2005.9523727.
[102] D.E. Hunnes, The effects of weather, household assets, and safety-net programs on household food security in Ethiopia using rural household panel data, Reg. Environ. Change 15 (2015) 1095–1104.

[103] M. Tewodaj, The reach of rural services in Ethiopia: an asset and gender-based public expenditure benefit incidence analysis, Eur. J. Dev. Res. 25 (2) (2013) 230–251.
[104] S. Doocy, T. Shimeles, D. Norell, G. Burnham, Credit program outcomes: coping capacity and nutritional status in the food insecure context of Ethiopia, Soc. Sci. Med. 60 (2005) 2371–2382.
[105] Z. Woldegebrial, G. van Huylenbroeck, H. Assefa, M.G. Chandrakanth, S. Speelman, Adoption of small-scale irrigation and its livelihood impacts in northern Ethiopia, Irrigat. Drain. 64 (2015) 655–668.
[106] A. Enyew, T. Akalu, B. Mati, Impacts of long-term soil and water conservation on agricultural productivity: the case of Anjenie watershed, Ethiopia, Agric. Water Manag. 117 (2013) 55–61.
[107] A.A. Berhe, Coping with Drought for Food Security in Tigray, Ethiopia, Wageningen University and Research, 2011.
[108] A. Warren, M. Khogali, Desertification and Drought in the Sudano–Sahelian Region 1985–1991, United Nations Sudano-Sahelian Office (UNSO), New York, 1992.
[109] CSA, Population and housing census of Ethiopia. Central statistical authority of the federal democratic republic of Ethiopia, Addis Ababa (2007). http://unstats.un.org/unsd/censuskb20/Attachment489.aspx.
[110] G. Tesfay, G. Gebresamual, A. Gebretsadik, A. Gebrelibanos, Y. Gebremeskel, T. Hagos, Participatory Rural Appraisal Report: Alaje Woreda, Tigray Region, CASCAPE Working Paper 2.6.1, 2014.
[111] A. Jones, H. Breuning-Madsen, M. Brossard, A. Dampha, J. Deckers, O. Dewitte, T. Gallali, S. Hallett, R. Jones, M. Kilasara, et al., Soil Atlas of Africa, Publications of the European Union, Luxembourg, 2013.
[112] A. Dereje, Enhancing wheat productivity, end-use quality and value chain through community action research in northern Ethiopia, ANNUAL PROJECT REPORT 2015-2016 WHEAT VALUE CHAIN CARP (RUFORUM Grant No. RU 2014 CARP 05) (2016).
[113] T. Gebreegziabher, Climate change and adaptation strategies at smallholder Farmer's level the case of three districts of Tigray, northern Ethiopia, Doctoral dissertation, St. Mary's University) (2014).
[114] T. Kahsay, A. Lemma, Z. Marsie, Local perception, effect and coping mechanism of food aid and determinants of dependency syndrome: the case of Raya Azebo Woreda, Southern Tigray, Ethiopia, ISABB Journal of Food and Agricultural Sciences 10 (1) (2021) 1–12.
[115] A. Bsrat, N. Berhe, M. Balkew, et al., Epidemiological study of cutaneous leishmaniasis in Saesie Tsaeda-emba district, eastern Tigray, northern Ethiopia, Parasites Vectors 8 (2015) 149, https://doi.org/10.1186/s13071-015-0758-9.
[116] F. Watson, N. Bekele, C. Dolan, J. Shoham, A. Hall, Quality and potential use of data collected during nutrition surveys: an analysis of surveys in Ethiopia, International Health 3 (2011) 85–90.
[117] D. Maxwell, B. Vaitla, J. Coates, How do indicators of household food insecurity measure up? An empirical comparison from Ethiopia, Food Pol. 47 (2014) 107–116.
[118] R. Kraaijvanger, C.J.M. Almekinders, A. Veldkamp, Identifying crop productivity constraints and opportunities using focus group discussions: a case study with farmers from Tigray, NJAS 78 (2016) 139–151.
[119] W. Tesfamicheal, S. Di Falco, T. Berger, W. McClain, You are not alone: social capital and risk exposure in rural Ethiopia, Food Secur. 8 (2016) 799–813.
[120] R. Cavatassi, L. Lipper, P. Winters, Sowing the seeds of social relations: social capital and agricultural diversity in Hararghe Ethiopia, Environ. Dev. Econ. 17 (2012) 547–578.
[121] Food and Agriculture Organisation (FAO), Fifth World Food Survey, United Nations Food and Agriculture Organization, Rome, 1987.
[122] UNICEF, The State of the World's Children 2014 in Numbers: Every Child Counts, vol. 3, UNICEF, New York, 2014.
[123] G. Haysom, G. Tawodzera, "Measurement drives diagnosis and response": gaps in transferring food security assessment to the urban scale, Food Pol. 74 (2018) 117–125.
[124] C. Carletto, A. Zezza, R. Banerjee, Towards better measurement of household food security: harmonizing indicators and the role of household surveys, Global Food Secur. 2 (1) (2013) 30–40.
[125] T.J. Ballard, A.W. Kepple, C. Cafiero, The Food Insecurity Experience Scale: Development of a Global Standard for Monitoring Hunger Worldwide, vol. 61, FAO, Rome, 2013.
[126] Indranil Dutta, Gundersen Craig, 3 measures of food insecurity at the household level, in: Basudeb Guha-Khasnobis, Shabd S. Acharya, Benjamin Davis (Eds.), Food Security: Indicators, Measurement, and the Impact of Trade Openness, WIDER Studies in Development Economics (Oxford, 2007; online edn, Oxford Academic, 2008, https://doi.org/10.1093/acprof:oso/9780199236558.003.0003. (Accessed 14 September 2023).
[127] W. Kiboi, J. Kimiywe, P. Chege, Determinants of dietary diversity among pregnant women in Laikipia County, Kenya: a cross-sectional study, BMC Nutr 3 (2017) 12, https://doi.org/10.1186/s40795-017-0126-6.
[128] G. Kennedy, T. Ballard, M.C. Dop, Guidelines for measuring household and individual dietary diversity, Food and Agriculture Organization of the United Nations (2011).
[129] B. Vaitla, J. Coates, L. Glaeser, C. Hillbruner, P. Biswal, D. Maxwell, The measurement of household food security: correlation and latent variable analysis of alternative indicators in a large multi-country dataset, Food Pol. 68 (2017) 193–205.
[130] P. Bilinsky, A. Swindale, Months of Adequate Household Food Provisioning (MAHFP) for Measurement of Household Food Access: Indicator Guide, FHI, Washington, DC, 2010, p. 360 (version 4).
[131] D. Filmer, L.H. Pritchett, Estimating wealth effects without expenditure data or tears: an application to educational enrolments in states of India, Demography 38 (2001) 115–132.
[132] J. Hoddinott, T.J. Mekasha, Social protection, household size, and its determinants: evidence from Ethiopia, J. Dev. Stud. 56 (10) (2020) 1818–1837.
[133] L. David, Ethiopia poverty and gender update growth and gender inequalities in Ethiopia. Gender Analysis of the Ethiopian Household Survey, 2008.
[134] B. Yu, A. Nin-Pratt, J. Funes, S.A. Gemessa, Cereal production and technology adoption in Ethiopia, Internat. Food Policy Research Inst 31 (2011).
[135] R. Zimmermann, M. Brüntrup, S. Kolavalli, K. Flaherty, Agricultural policies in Sub-Saharan Africa: understanding CAADP and APRM policy processes (No. 48). Studies.Mendola, M. Agricultural technology adoption and poverty reduction: a propensity-score matching analysis for rural Bangladesh, Food Pol. 32 (3) (2009) 372–393, https://doi.org/10.1016/j.foodpol.2006.07.003, 2007.
[136] G.W. Muluken, M. Sassi, Impact of agricultural interventions on food and nutrition security in Ethiopia: uncovering pathways linking agriculture to improved nutrition, Cogent Food Agric. 6 (1) (2020) 1724386, https://doi.org/10.1080/23311932.2020.1724386.
[137] B. Thompson, L. Amoroso (Eds.), Improving Diets and Nutrition: Food-Based Approaches, CABI, 2014.
[138] D. Mosha, C.R. Canavan, A.L. Bellows, M.M. Blakstad, R.A. Noor, H. Masanja, J. Kinabo, W. Fawzi, The impact of integrated nutrition-sensitive interventions on nutrition and health of children and women in rural Tanzania: study protocol for a cluster-randomized controlled trial, BMC nutrition 4 (2018) 1–8.
[139] M.H. Forouzanfar, A. Afshin, L.T. Alexander, H.R. Anderson, Z.A. Bhutta, S. Biryukov, M. Brauer, R. Burnett, K. Cercy, F.J. Charlson, A.J. Cohen, Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015, The lancet 388 (10053) (2016) 1659–1724.
[140] J. Hoddinott, H. Derek, D. Cows Mekdim, Missing milk markets, and nutrition in rural Ethiopia, J. Dev. Stud. 51 (8) (2015) 958–975.
[141] D. Headey, H. Kalle, Is exposure to poultry harmful to child nutrition? An observational analysis for rural Ethiopia, in: Jacobus van Wouwe (Ed.), PLoS One 11 (8) (2016) e0160590. Public Library of Science.
[142] L. Kimenye, Best-bet technologies for addressing climate change and variability in Eastern and Central Africa. ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa): Entebbe, Uganda, 2014. July, 2015.
[143] S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. Averyt, M. Tignor, H. Miller, IPCC fourth assessment report (AR4), Clim. Change 374 (2007).
[144] J. Schmidhuber, F.N. Tubiello, Global food security under climate change, Proc Natl Acad Sci. 4 (50) (2007) 19703–19708.
[145] C. Andersson, A. Mekonnen, J. Stage, Impacts of the Productive Safety Net Program in Ethiopia on livestock and tree holdings of rural households, J. Dev. Econ. 94 (1) (2011) 119–126.

[146] H.M. Afeworki, B. Adam, Farmers perception on climate change and determinants of adaptation strategies in benishangul-Gumuz regional state of Ethiopia, Int. J. Food Syst. Dynam. 9 (5) (2018) 453–469, https://doi.org/10.18461/ijfsd.v9i5.956.
[147] D. Zilberman, J. Zhao, A. Heiman, Adoption versus adaptation, with emphasis on climate change, Ann Rev Resource Econ 4 (1) (2012) 27–53, 1941-1340/12/1010-0027$20.00.
[148] C. Barrett, T. Reardon, P. Webb, Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications, Food Pol. 26 (4) (2001) 315–331.
[149] J. Van Etten, E. Beza, L. Calderer, K. Van Duijvendijk, C. Fadda, B. Fantahun, Y.G. Kidane, J. Van de Gevel, A. Gupta, D.K. Mengistu, D.A.N. Kiambi, First experiences with a novel farmer citizen science approach: crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies (tricot), Exp. Agric. 55 (S1) (2019) 275–296. Mabaya, E., 2016. Performance of the formal seed sector in Africa: Findings from the African seed access index (No. 310-2016-5355).
[150] V. Simone, B.G. Munyua, M. Kai, J.D. Michler, Welfare impacts of improved chickpea adoption: a pathway for rural development in Ethiopia? Food Pol. 66 (2017) 50–61.
[151] F. Fao, The State of Food and Agriculture: Climate Change, Agriculture and Food security. Rome, Italy, 2016.
[152] A.H. Mesfin, K.G. Gebremedhin, Y.T. Birhan, T. Yohannes, H. Weldeyesus, T. Tefera, M. Diro, R. Vonk, D. Confidence, N. Teferi, D. Fikadu, Weather information and shocks: policy implications to ensure food security in Tigray Region of Ethiopia, J. Arid Environ. 205 (2022) 104769.
[153] World Bank, Doing Business 2014: Understanding Regulations for Small and Medium-Size Enterprises, The World Bank, 2013.