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SCHOOL OF POST-GRADUATE STUDIES

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DEPARTMENT OF BIOLOGY

NEGLECTED AND UNDERUTILIZED ROOT AND TUBER CROPS, THEIR PROVISIONING ECOSYSTEM SERVICES, AND TRADITIONAL MANAGEMENT PRACTICES, IN MERAB BADAWACHO WOREDA, HADIYA ZONE, CENTRAL ETHIOPIA

MSc THESIS

BY :- TARIKU TAREKGN

MAY, 2024

HAWASSA, ETHIOPIA

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A THESIS SUBMITTED TO THE DEPARTMENT OF BIOLOGY, COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES, SCHOOL OF GRADUATE STUDIES, HAWASSA UNIVERSITY IN PARTIAL FULIFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCES IN BIOLOGY (**BOTANICAL SCIENCE)**

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ADVISORS' APPROVAL SHEET

This is to certify that the M.Sc. Thesis entitled "**NEGLECTED AND UNDERUTILIZED ROOT AND TUBER CROPS, THEIR PROVISIONING ECOSYSTEM SERVICES, AND TRADITIONAL MANAGEMENT PRACTICES, IN MERAB BADAWACHO WOREDA, HADIYA ZONE, CENTRAL ETHIOPIA**" Submitted in partial fulfillment of requirement for degree of masters of Science in Biology the graduate program of **department of biology** and has been carried out by **Tariku Tarekgn Anshebo ID: GpBotsR/0008/14),** under my/our supervision. Therefore I/we recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by **Tariku Tarekgn** have read and evaluated his/her thesis entitled **"NEGLECTED AND UNDERUTILIZED ROOT AND TUBER CROPS, THEIR PROVISIONING ECOSYSTEM SERVICES, AND TRADITIONAL MANAGEMENT PRACTICES, IN MERAB BADAWACHO WOREDA, HADIYA ZONE, CENTRAL ETHIOPIA**" and examined the candidate. This is to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in **BOTANICAL SCIENCE** with Specialization in Biology.

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DEDICATION

This thesis is dedicated to my wife Mitike Habtamu and my families for their moral support and encouragement in my entire career for the success of my life.

DECLARATION

I, the undersigned, declare that this is my original work and has never been presented in this or any other University and that all the source materials used for this thesis have been duly acknowledged;

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The thesis has been submitted for examination with my approval as a University advisor.

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LIST OF ABBREVIATIONS AND ACRONYMS

CSA	Central Statically Agency
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical
IK	Indigenous Knowledge
IWM:	Integrated Weed Management
m.a.s.l	Meter Above Sea Level
MBWFED	Merab Badawacho Woreda finance and Economic Development Office
NUFCS	Neglected and Underutilized Food Crops
NURTCS	Neglected and Underutilized Root and Tuber Crops

ABSTRACT

Root and tuber crops are high-yield potential crops mainly grown for multiple purposes in the home-gardens in Ethiopia. Despite these benefits, they are mostly neglected and underutilized as well as are given little attention by both policy-makers and researchers. This study evaluated the neglected and underutilized root and tuber crops (NURTCs), their provisioning ecosystem services, and traditional management practices in Hadiya zone, Central Ethiopia. The study site was selected using a purposive sampling technique. Relevant data were gathered using questionnaire household survey, semi-structured interviews, field observations, and key informant interviews. The study engaged a total of 320 sample households from the selected sites. The most widely used NURTCs in terms of food; income and traditional medicine were Enset (Ensete ventricosum (Welw.) Cheesman), Taro (Colocasia esculenta (L.) Schott)), Sweet potato (Ipomoea batatas (L.) Lam), Ethiopian potato (Plectranthus edulis (Vatke) Agnew) and Yams (Dioscorea spp.). These crops delivered multiple provisioning ecosystem services, including source of food, income, livestock feed and traditional medicine. The crops were used as main food and food supplements by the majority of households, contributing a major share to the traditional food system. About 83.4%, 56.5% and 33.4% of the households used the crops for income generation, traditional medicine and animal feed, respectively. The major traditional management practices were mixed cropping, crop rotation, fallowing land, storing of planting materials, and pest management. Households practiced manual methods to control weed, pest and disease. They used different indigenous soil fertility management mechanisms, with 98.4% of them using animal manure to increase soil fertility, productivity and ecosystem services. Despite those benefits and rich management systems, the production of the crops were declining as witnessed by about 85% of the households, indicate their vulnerability to genetic erosion. An increase in population size, shrinking in home-garden size, and new weeds, pests and disease were the main contributor for their decline. Overall, the NURTCs provide multiple ecosystem services such as food, income, livestock fodder, and medicine and are mainly managed by traditional knowledge and skill. As they are the vital part of livelihood systems, there should be a support from all key stakeholders regarding addressing the bottlenecks constraining the production, productivity and gene conservation of the NURTCs that are effective in giving greater yield per unit farm, and providing multiple provisioning ecosystem services.

Keywords: Ecosystem service, Indigenous knowledge; Management practice; Neglected crop, Traditional home-garden, Underutilized crop.

1. INTRODUCTION

1.1 Background of the Study

Ethiopia has diverse agro-ecological and climatic conditions suitable for the production of various crops including root and tuber crops. Despite these facts, little research and development attention have so far been given to these crops. Hence, the food potential of root and tuber crops has not yet been fully exploited (Yeshital Mekbib and Temesgen Deressa, 2016). Root and tuber crops contribute a major share in the traditional food systems of many people in Ethiopia. Especially, they play a vital role in the food security of the people in South and South western parts of Ethiopia (kusse kutoya, 2021). These parts of the country have got a long history of cultivation and use of root and tuber crops as a staple diet. The major indigenous root and tuber crops of the country include: Enset (*Ensete ventricosum* (Welw.) Cheesman), Anchote (*Coccinia abyssinica* (Lam.) Cogn.), Ethiopian potato (*Plectranthus edulis* (Vatke) Agnew) and Yams (*Dioscorea abyssinica*). The exotic species include Taro (*Colocasia esculenta* (L.) Schott), Tannia (*Xanthosoma sagittifolium* (L.)Schott), Cassava (*Manihot esculenta* Crantz), Potato (*Solanum tuberosum* L.) and Sweet potato (*Ipomoea batatas* (L.) Lam.) (Eden Genetu *et al.*, 2023). These crops contribute a major share of traditional food system in Ethiopia. Currently, many of these crops are used as a major staple diet in South and Southwestern part of Ethiopia (IBC, 2008). Overlooked and underdeveloped indigenous food items that have huge potential for addressing the food and income needs of the farmers in Ethiopia. Among the others, neglected and underutilized root and tuber crop species that have huge potential for addressing the food and income needs of the farmers have been found in different parts of Ethiopia. They are important crops widely cultivated for their food, medicinal, and cultural values (Abebe Olkeba, 2019). Millions of people in Ethiopia depend on consumption of root and tuber, and legume crops as their major or supplementary food and sources of cash for small holder farmers (kusse kutoya, 2021). Root and tuber crops give greater yield per unit area than the major grain crops used as basic food. These crops can support greater density of population than other food crops when produced on small plots of land. Most of the indigenous root and tuber crops of Ethiopia are produced by smallholder farmers following indigenous knowledge (Negash

Geleta, 2019). This knowledge is generated and transmitted by communities, over time, in an effort to cope with their own agro-ecological and socio-economic environment. Indigenous knowledge is passed from generation to generation, usually by word of mouth and cultural rituals, and has been the basis for agriculture, food preparation and conservation and management practices, health care, education, and the wide range of other activities that sustain a society and its environment in many parts of the world for many centuries (Amare Seifu *et al.*, 2019).

The production of neglected and underutilized root and tuber crops still depended on local varieties maintained by farmers. Besides, little research attention was given to these crops (Yeshital Mekbib and Temesgen Deressa, 2016). In the modern agriculture more farmers depend on cash crops, which are produced by using improved varieties and agricultural inputs. Generally, neglected and underutilized root and tuber crops have given little attention as compared to other cash crops and vegetables and fruit crops in Ethiopia. Moreover, the root and tuber crops are grown as homestead/home-garden which usually produced and taking care by women farmers (Jemal and Callo-Concha, 2017). If neglected and underutilized crops are continually forgotten by research and development, the genetic diversities due to lack of attention; might be totally lost. On the other hand, if the attention is given by research and development works, then the production and productivity is improved and can support the greater part of the rural communities and to a lesser extent the urban communities. Therefore, the objective of the present study is to identify the composition of the widely grown neglected and underutilized root and tuber crops in the study areas as well as to evaluate their provisioning ecosystem services and indigenous management practices and associated challenges.

1.2 Statement of the Problem

Ensuring food security has become a major challenges although agriculture is the main stay of the majority of Ethiopians. This is constrained by abiotic and biotic factors (Yigezu Gebissa, 2020). In the coming decades, ensuring food security will continue to be one of the greatest challenges in Ethiopia. This is because of the rapid increment in population size, change of fertile farmland to construction for urban dwellers, climate change, and a decline of root and tuber crops (Zerihun Jalata, 2022). Most of the useful plant species diversity is almost lost by human impact and hence, there is obvious loss of biodiversity, disruption of indigenous knowledge, practices, and culture. Due to limited integration of traditional practices and modern science, the value of traditional farming in the conservation and management of root and tuber crops species by indigenous people is minimal and there is a problem of food insecurity.

Ethiopia is one of the world's most ethnically and culturally diverse countries, with over 70 different languages spoken across more than 80 distinct ethnicities (López, 2021). People of different cultural groups believed to have their own indigenous knowledge of farming practices, conservation, management and uses of root and tuber crops. Over the centuries, indigenous peoples have provided a series of ecological and cultural services to humankind. The preservation of traditional forms of managing knowledge and practices help maintain root and tuber crops, enhance food security and protect the world's natural resources (Bishaw Baye and Wubshet Teshome, 2020).

There are several cultivated or semi-cultivated root and tuber crops indigenous to Ethiopia, nevertheless, recent reports showed that there is a growing concern about the loss of genetic diversity for these 'minor' root and tuber crops which reduces its contribution to food security. The decline in the use of such crop species by users may cause the loss of genetic base and prevent distinctive and valuable traits being used in crop adaptation and improvement as well as research on minor' crops have been very globally low (FAO, 2010). This study, therefore, stems from this understanding and has the following general and specific objectives.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of this study was to evaluate the neglected and underutilized root and tuber crops, their provisioning ecosystem services and management practices and associated challenges in Merab Badawacho Woreda, Hadiya zone, Central Ethiopia.

1.3.2 Specific Objectives

- To identify the major root and tuber crops grown in home-gardens,
- To investigate the provisioning ecosystem services of root and tuber crops, and
- To identify the indigenous management practices and associated challenges of root and tuber crops.

1.4. Research Questions

1. What neglected and underutilized root and tuber crops are widely cultivated in home-gardens?

2. What are the major provisioning ecosystem services provided by the neglected and underutilized root and tuber crops?

3. How do local communities manage neglected and underutilized root and tuber crops? And challenges limiting the production of them?

1.5 Significance of the Study

This research has generated information on neglected and underutilized root and tuber crops, provisioning ecosystem services and traditional knowledge related to the management practices the crops. The findings from this study provide valuable information for policy makers, research institutes and researchers, regarding the huge

potential benefits of the crops for smallholder farming operating under land scarcity, increasing family size and food insecurity and related problems.

1.6 Scope of the Study

The study was conducted in Merab Badawacho Woreda Hadiya zone, Central Ethiopia. The scope of the study was restricted to three sample Kebeles (Elefeta, Ofoda and Weraboya). The study will focus on management practices and ecosystem services of neglected and underutilized root and tuber crops and associated indigenous knowledge.

1.7 Limitations of the Study

The study did not include the whole area of Merab Badawacho Woreda. It was limited only to selected kebeles based on the root and tuber crops composition and diversity as well as number of practicing households. Moreover, the study was limited in content focusing on the status of current neglected and underutilized root and tuber crops, ecosystem services and indigenous management techniques.

2. LITERATURE REVIEW

2.1 Definition and Meaning of Neglected and Underutilized Root and Tuber Crops

Neglected and underutilized root and tuber crops are not well researched and are underfunded due to their limited importance in the global food market, but are characterized by their resilience and adaptation to extreme climatic and edaphic conditions and have local significance (Mabhaudhi *et al.*, 2019). Underutilized crops "were once grown more widely or intensively but are falling into disuse for a variety of agronomic, genetic, economic and cultural reasons. Farmers and consumers are using these crops less because they are in some way not competitive with other species in the same agricultural environment. According to Mpandeli (2022) underutilized species are defined as species with underexploited potential for contributing to food security, health and nutrition, income generation and environmental protection. They may have different terms or names such as neglected, underutilized, minor, orphan, underexploited, underdeveloped, lost, new, novel, promising, alternative, local, traditional, niche …crops. The decline of these crops may erode the genetic base and prevent distinctive and valuable traits being used in crop adaptation and improvement. Neglected and underutilized root and tuber crop varieties are best suited to local environmental conditions and to the needs of farmers in marginal agricultural situations (Chivenge *et al*., 2015). Their low input requirements give them an economic advantage over adapted crops like maize, rice and wheat (Chibarabada *et al.*, 2017).

2.2 Definitions and Concepts of Indigenous Knowledge

Indigenous knowledge (IK) is unique to a particular culture and society. It is also known as local knowledge, folk knowledge, people's knowledge, traditional wisdom or traditional science. It is the basis for local level decision-making in agriculture, food preparation, education, natural resource management, and a host of other activities in rural communities Such knowledge is passed down from generation to generation, in many societies, orally, or transmitted through imitation and demonstration (Abebe Olkeba, 2019).

IK is a key element of the social capital of the poor; their main asset to invest in the struggle for survival, to produce food, to provide for shelter or to achieve control of their own lives. IK is tacit knowledge that is difficult to codify and embedded in community practices, institutions, relationships, and rituals. It is a consequence of practical engagement in everyday life and is constantly reinforced by experience, trial, and error. Herbal medicine is a good example of IK, which has affected the lives of people around the globe. Rankoana (2017) shows that the farming community has ample knowledge of the types of crops which adapt well on particular soil types and mulching practices to maintain soil fertility. For centuries, farmers have planned agricultural production and conserve natural resources with the mechanisms of indigenous knowledge (Masarat Elias, 2018). Farmers carry out various indigenous crop production practices most of which were cross-cutting among the crops grown. In this regard, early planting is one of the pillars for both indigenous and improved farming methods. Farmers take advantage of early rains, which help them to reduce the incidences of pests and disease that leads to high yields (Akullo *et al*., 2007).

Report shows that in some countries, local crop varieties are conserved in a gene bank. The gene bank preserves the genetic information of indigenous varieties in hope that genetic traits of these species may corroborate instrumental in future breeding programs against pests and disease. Similarly, Akullo *et al.* (2007) indicated that farmers in Uganda use rudimentary post-harvest handling techniques. Due to the fact that many root crops are highly perishable when harvested, for instance, when farmers harvest cassava and not immediately used for consumption or selling, the fresh tubers are buried in moist soil. In agreement with the findings of the current study as the growers use in situ or ground for preserving neglected and underutilized root and tuber crops (Abebe Olkeba, 2019).

2.3. Production of Root and Tuber Crops in the World

Globally root and tuber crops are grown in an area of 67 million ha with a production of 887 million tonnes in 2017 (FAOSTAT, 2019). Among the tuber crops, potatoes contribute a significant share to the total global production, followed by cassava, sweet

potatoes, yams, taro and other roots and tubers. Root and tuber crops are grown in area of 67 million ha with a production of 887 million tons and having average productivity of 11 t/ha. Among the tuber crops, cassava is the most important tropical tuber crop and also a staple food crop in many of the African countries. Potatoes accounted for about 44 % of the overall root and tuber crop production in the world, followed by cassava (32.91%), sweet potatoes (12.72%) and yams (8.23 %). Though potatoes lead in the production among the tuber crops, cassava holds the top spot in the area under cultivation. Besides area and production, potatoes (20.1 t/ha) and sweet potatoes (12.26 t/ha) witnessed the highest productivity among the tuber crops (Prakash *et al*., 2020)

In India, cassava and sweet potatoes are the most important tuber crops due to its large area under cultivation and its varied uses. Cassava is mainly cultivated in the southern parts of India. In Tamil, Nadu, cassava is mainly used as a raw material for starch and sago factories, whereas in Kerala, cassava is a popular secondary staple food, while sweet potatoes are mainly grown in Odisha, Kerala and West Bengal. Mostly, it is used for human consumption and as a cattle feed to some extent (Prakash *et al*., 2018; Srinivas and Nedunchezhiyan, 2020)

2.4. Production of Root and Tuber Crops in Africa

The root and tuber crop farming system is a traditional farming system of the wet humid forest and the forest-savannah transitional agroecological zones in west and central Africa. In recent times, cassava and sweet potatoes are facing threats from other crops due to decline in tuber prices, easy availability, access to tasty and convenient foods in the rural areas. The relative importance of these crops is evident through their annual global production which is approximately 836 million tonnes (FAOSTAT, 2013). Asia is the main producer followed by Africa, Europe, and America. Asian and African regions produced 43 and 33%, respectively, of the global production of roots and tubers. A number of species and varieties are consumed but cassava, potatoes, and sweet potatoes consist of 90% global production of root and tuber crops (FAOSTAT, 2013). The root and tuber crop farming system occurs in west and central Africa, bounded on the southern, wetter side by the tree crop farming system and on the northern, drier side by

the cereal-root crop mixed farming system. The root and tuber crop farming system occupies an estimated 236 million ha and has an estimated human population of 112 million, of whom over 50 per cent live in rural areas.

The system has a humid tropical climate with, on average, a nine-month growing season. These climatic conditions support the characteristic root and tuber crops (cassava, cocoyam, yam and sweet potatoes) complemented by some tree crops (oil palm, cocoa, rubber, cashew and mangoes) and cereals (maize, rice, sorghum and millet) and small numbers of livestock – making it a highly diverse and complex farming system with stable and relatively high potential food productivity. The farming system is at an early stage of development, mainly focused on household food security. Markets are generally poorly developed, although there are pockets of semi-commercial farming. Total cultivated area is nearly 23 million ha, of which little is irrigated. Farm sizes are generally small, usually less than 2 ha. Crop production is mostly subsistence. Female members of farm households have an important role in the farming system, especially in the production and processing of root and tuber crops (FAOSTAT, 2013).

The characteristic root and tuber crops cultivated in the farming system are cassava (*Manihot esculenta*), yams (*Dioscorea spp.*), cocoyams (*Xanthosoma spp*.), sweet potato (*Ipomoea batatas*) and potato (*Solanum tuberosum*). Farmers cultivate these crops on about 47 percent of the typical farm. (These same root and tuber crops are found in other African farming systems, but often play more modest roles.) Within the root and tuber crop farming system, other important sources of farm livelihoods include maize (*Zea mays*), rice *(Oriza sativa*) and off-farm income sources such as trading, craft and salaried work.

2.5. Production of Root and Tuber Crops in Ethiopia

The production of neglected and underutilized root and tuber crops still depended on local varieties maintained and managed by farmers. These crops are important source of food for rural people. These crops contribute a major share of traditional food system in Ethiopia. They are edible, energy-rich underground plant structures developed from

modified roots while tuber crops are those crops in which the edible carbohydrate rich storage organs develop wholly or partly from underground stems. The main root and tuber crop in Ethiopia include enset, potato, taro, yams, anchote, cassava and sweet potato (Eden Genetu *et al*., 2023). Neglected and underutilized root and tuber crop species that have huge potential for addressing the food and income needs of the farmers have been found in different parts of Ethiopia. Among the others, Ethiopian potato (*Plectranthus edulis*) and anchote (*Coccinia abyssinica*) are native to Ethiopia and important tuber crops widely cultivated for their food, medicinal, and cultural values (Abebe olkeba, 2019).The genetic resources of traditional root and tuber, and legumes crops are to a large extent left to indigenous and natural processes, although crops presumed to be of high potential (Negash Geleta, 2019).

2.6. Uses of Neglected and Underutilized Root and Tuber Crops

Root and tuber crops, namely potatoes, cassava, sweet potatoes, yams and other minor tuber crops are important to agriculture, food security and income for about 2.2 billion people in developing countries (Parkish *et al.,* 2020). Root and tuber crops are second only in importance to cereals as global sources of carbohydrates. They provide a substantial part of the world's food supply and are also an important source of animal feed and processed products for human consumption and industrial use. In Ethiopia these neglected and underutilized root and tuber crops were used for food, sale, animals' feed, traditional medicinal use and traditional food preparation (Amare Sifu *et al*., 2019)

2.6.1 Uses of neglected and underutilized root and tuber crops in food security in Ethiopia

Current changing environments in Ethiopia characterized by extreme droughts and shortened rain seasons, favour the cultivation of root and tuber crops. These crops helped to ensure food and nutrition security as part of a balanced diet, when adapted crops fail, or in between harvests. They provide important vitamins, proteins and micronutrients, and can contribute to alleviating the challenges of stunting in children in developing countries (Chivenge *et al*., 2015; Demelash Hailu, Ayana Fikadu, 2020). The role of

neglected and underutilized food crops has long been an intimate part of local cultures and traditions. Many neglected and underutilized food crop species play a role in keeping alive cultural diversity associated with food habits, health practices, religious rituals and social exchanges. The role of neglected and underutilized foods crops is an effective way to help a diverse and healthy diet and to combat micronutrient and deficiencies, the so called 'hidden hunger' and other dietary deficiency particularly among the rural poor and the more vulnerable social groups in developing countries (Osewa *et al.,* 2013).

2.6.2 Socio-economic importance of neglected and underutilized root and tuber crops

The role of underground starchy crops in global food security is widely recognized. These are subsistence crops considered as neglected and underutilized. However, these have become the new focus of international community for providing income opportunities and presenting different potential uses. The social and economic trajectories of most South American countries are linked to these crops, with emphasis on cassava, yams, potatoes, and sweet potatoes, responsible for 93% of the root and tuber species consumed worldwide. However, there are several other neglected plant species that are cultivated by traditional communities with commercial-scale potential. These were not widely recognized in the literature and mainly include contain phosphorus, mucilage, and high levels of phenolic compounds (Siqueira *et al.,* 2023).

Neglected and underutilized crops are essential to the livelihoods of millions of poor farmers throughout the world. Orphan crops play particular role in food security, nutrition, and income generation to resource-poor farmers and consumers in developing countries. These crops perform better than major crops of the world under extreme soil and climatic conditions prevalent in developing world particularly in Africa (Parkish *et al.*, 2018).

2.6.3 Medicinal uses of neglected and underutilized root and tuber crops

In Ethiopia neglected and underutilized root and tuber crops used as traditional medicine. Root and tuber crops, namely potatoes, cassava, sweet potatoes, yams and

other minor tuber crops are important to agriculture, food security and medicinal uses. The diseases treated by neglected and underutilized root and tuber crops and their wild relatives are stomach ache occur after delivery (stomach bloating, kidney infection, common cold, arthritis, gastritis, wound caused by accident, ringworm, malaria, abscess, itch, cattle bloating, earache, fungal diseases, broken bone, Hypertension, Brain tumor, dermatomycosis, to get ride off leech from the mouth of cattle and ulcer (Amare Seifu *et al.*, 2019; Siqueira *et al.*, 2023).

2.6.4. Agronomic advantage of root and tuber crops

Roots and tuber crops are important cultivated staple energy sources, second to cereals, generally in tropical regions in the world. They include potatoes, cassava, sweet potatoes, yams, and aroids belonging to different botanical families but are grouped together as all types produce underground food. An important agronomic advantage of root and tuber crops as staple foods is their favorable adaptation to diverse soil and environmental conditions and a variety of farming systems with minimum agricultural inputs. In addition, variations in the growth pattern and adopting cultural practices make roots and tubers specific in production systems (Chandrasekara and Kumar, 2016)

2.6.5. Nutritional value of root and tuber crops

Neglected and underutilized root crops can contribute to food and nutrition security being high in calorific values and other essential nutrients. They have a great potential to provide economical sources of dietary energy, in the form of carbohydrates (Yeshitila & Temesgen, 2016) According to Chandrashekara and Kumar (2016), root and tuber crops (RTCs) are the second highest source of carbohydrates after cereals. The energy from tubers is about one-third of that of an equivalent weight of rice or wheat due to high moisture content of tubers. However, high yields of roots and tubers give more energy per land unit per day compared to cereal grains. In general the protein content of roots and tubers is low ranging from 1 to 2% on a dry weight basis.

Potatoes and yams contain high amounts of proteins among other tubers. Sulphur-containing amino acids, namely, methionine and cystine, are the limiting ones in root

crop proteins. Cassava, sweet potatoes, potatoes, and yam contain some vitamin C and yellow varieties of sweet potatoes, yam, and cassava contain β-carotene. Taro is a good source of potassium. Roots and tubers are deficient in most other vitamins and minerals but contain significant amounts of dietary fibre (Chandrasekara and Kumar, 2016). Similar to other crops, nutritional value of roots and tubers varies with variety, location, soil type, and agricultural practices, among others.

2.7 Reasons for Encouraging Root and Tuber Crops Production Management Practices in Ethiopia

There are many realistic reasons for encouraging root and tuber crops production management practices in Ethiopia. First and most importantly, they are one of the most adaptable staples to address food security for millions of people, and produce more food per unit area of land. This may have a meaningful contribution to avoid chronic food insecurity in Ethiopia. Second, they are nutritionally rich staple foods that contribute protein, vitamins (A and C), zinc, and iron towards the dietary demands of the society (Sanginga and Mbabu, 2015). However, the nation still suffers from malnutrition, for example, vitamin A deficiency (EIAR, 2015). The third realistic reason is that some of these crops are suitable for double cropping. For example, potato and sweet potato are one of the short cycling crops with three to four months cropping cycle which are well suited to the double cropping particularly in rain-fed systems (Sanginga and Mbabu, 2015). Fourth, these crops insure sustainable food availability throughout the year. In this case root and tuber crops even with longer cropping cycles are quite essential. The longer cropping cycle crops such as yam, cassava and enset for instance play a vital role for annual cycle of food availability. In addition, most of these crops are the known climate resilient crops withstanding the unforeseen climatic conditions. For instance, enset is one of the drought tolerant food security crops, where it supplements human calorie requirements of around 20 million people in Ethiopia. The crop also has an enormous potential in other regions of sub-Saharan Africa, where it is known only as a wild plant (Semerdin Yimer and Tsegaye Babege, 2018).

There are other vegetables and root crops which are very important in sustaining food security among the rural community but no attention is given in research and development (for instance; oromo potato (*Plectranthusedulis* (Vatke) Angew); *Dioscoria spp* and taro (*Colocasia esculenta* (L.) Schott) (Yeshitila Mekbib & Temesgen Deressa, 2016). Generally, neglected and underutilized root and tuber crops had no attention as compared to other field crops and vegetables and fruit crops in Ethiopia. Moreover, the root and tuber crops are grown as homestead/ home garden which usually produced and taking care by women farmers (Jemal and Callo-Concha, 2017).

2.8 Indigenous Management Practices of Neglected and Underutilized Root and Tuber crops

Indigenous management practices on neglected and underutilized root and tuber crops are mainly agronomic and structural systems, which have supported one of the densest rural populations in rural Ethiopia since immemorial. Currently in Ethiopia indigenous management practiced are use of manure, agro forestry, crop rotation, intercropping, fallow land and management practices such as soil bund and terrace (Amare Seifu *et al.*, 2019).

Farm land owners use various forms of plant management strategies in home gardening activities (Yirefu Tefera *et al.,* 2019). Farmers have developed a collection of complex indigenous useful home garden plant system that are adapted to local conditions and designed to meet local needs. These indigenous agro forestry systems are rich sources of knowledge about the cultivation of perennial species in different time and space arrangements with annual crops (Getahun Yakob, 2014). In the management of root and tuber crops traditional or indigenous knowledge plays a critical role. It includes different sets of complex practices. The decisions related to the selection of crops, procuring inputs, harvesting, and management and forth are mostly driven by consumption and income generation needs of the households (Yirefu Tefera *et al.,* 2019)

2.8.1 Indigenous methods for controlling weeds

According to Tikai (2010), the majority of smallholder farms in Samoa still practice cultural methods such as pull and burn, mulching, shifting cultivation, fallowing, slash and burn, intercropping, cover cropping and shallow cultivation to control weeds in the garden. It is clear from the result that 60%-70% of farmers in Samoa are practicing the indigenous method of "pull and burn" and "fallowing" to control weeds of root and tuber crops.

Indigenous control methods using mulching, fallowing, intercropping and planting cover crops are effective in controlling weeds. Intercropping has proven its ability to suppress weeds basically through two strategies. Intercrops may exert resource competition with weeds and may involve in allelopathic interactions, which are detrimental to the growth of weeds (Arora *et al.*, 2015). However, in some instances, the intercropping system by itself would not be able to provide a satisfactory level of weed control unless the best component crops are selected along with the best compatible environmental condition **(**Weerarathne et *al.*, 2017)

2.8.2 Indigenous methods of controlling pests and diseases

The cassava green mite is an important pest of cassava in Africa that can cause significant losses in yield. The mite can easily be spread from one place to another on leaves and cuttings of the plant, and by wind. An integrated approach is required to control the pest and reduce the damage. Cultural practices, such as using clean planting material, planting early in the rain season and intercropping with pigeon pea, can reduce populations of the pest (ASHC, 2015).

Sweet potato weevils are insect pests that can cause severe damage to sweet potatoes. The larvae cause the most damage by feeding on the stems and storage roots. According to Tikai (2010) farmers in Samoa have practiced various indigenous knowledge to control pests and disease even before the advent of modern synthetic insecticides. Most of the indigenous insect pest control methods were to disrupt pests' life cycle by periodically denying their food and to achieve the maximum control the manipulation of

ordinary agricultural practices would follow. In the traditional agriculture, farmers have a wealth of knowledge in tackling varieties selection and cultivations, pest and diseases management which are generally well adapted to their socioeconomic and environmental conditions. Since Enset is an indigenous crop, almost all production and processing practices are based on farmers' experiences. The use of indigenous knowledge in propagation, transplanting, inter-cropping, harvesting/ processing, protection from pests and diseases are valuable (Belachew Garedew *et al.,* 2017).

2.8.3. Indigenous methods of cultivation and maintaining soil fertility

Mixed cropping is one of the frequently used indigenous methods of maintaining soil fertility for the root and tuber crops surveyed. It also increases productivity of root and tuber crops. According to Tofiga (2003), he described mixed cropping as the growing two or more crops simultaneously on the same piece of land with or without distinct row management. Mixed cropping systems create favorable condition for the soil, water, nutrients and provide excellent environmental conservation and sustainability (Belachew Garedew *et al.,* 2017).

According to Yeshitila & Temesgen (2016), neglected and underutilized root and tuber crops produce in monoculture and in multiple-cultures. Growers practiced intercropping with maize, sugarcane, and cabbage when they intend to produce the true seed. Their motives for intercropping with other crops are to get additional yield from the same land and provide the post to the plant and produce the true seed. However, the main practice is a monoculture.

2.8.4. Indigenous methods of harvesting and storage of root and tuber crops

Indigenous methods of harvesting and storage of the root and tuber crops surveyed. Some traditional storage systems that are used to store roots crops. Taro, yam, taamu, together with cooking bananas (plantains) are perishable stable food crops. Many communities in Samoa traditionally practice a greater or lesser degree of "storage avoidance", i.e. harvesting only for immediate or short term requirements throughout much of. Or even the whole year. Thus, storage systems are usually relatively short term

(the yams, the most highly seasonal of the perishable crops, provide a marked exception, many traditional communities in Samoa have been primarily dependent on the perishable staples for centuries or often millennia, have devised many highly ingenious storage and processing techniques for these staples (Tikai and kama, 2010).

By Indigenous method taro harvest 6-12 months and storage in pit and Store in cool place (shade). By indigenous method community harvested yams twice a year. The first harvest is when the tubers are large and the second is when the tubers die. The storage life of yams is finally terminated by breaking of dormancy and subsequent sprouting but storage of tubers for food use can be extended by as much as month by breaking off emergent sprouts when they are 20-30 mm long. Most farmers in traditional yam growing societies are well aware that only sound healthy tubers are suitable for storage and others are set aside for consumption and processing (Tikai and Kama, 2010).

According to Mpandeli (2022) underutilized species are defined as species with underexploited potential for contributing to food security, health and nutrition, income generation and environmental protection. They may have different terms or names such as neglected, underutilized, minor, orphan, underexploited, underdeveloped, lost, new, novel, promising, alternative, local, traditional, niche …crops. If neglected and underutilized crops are continuing forgotten by research and development, the genetic diversities due to lack of attention; might be totally lost. On the other hand, if attention is given, by research and development works the production and productivity is improved and it can support the greater part of the rural communities and to a lesser extent the urban communities.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Geographical location of the study area

This study was conducted in Merab Badawacho Woreda of Hadiya Zone, Central Ethiopia. Geographically, the Woreda is located between $7^0$4'0" to $7^0$14'30" latitude and $37^0$45'30" to $37^0$52'30" longitude (Fig.1). The Woreda is located about 357 km south west of the capital city of the country. It is bordered by Kambata Tambaro Zone in the north and north-east and by Misrak Badawacho in the east and by Wolaita Zone in the south and Kachabira Woreda in the north-west (MBWFED, 2018).

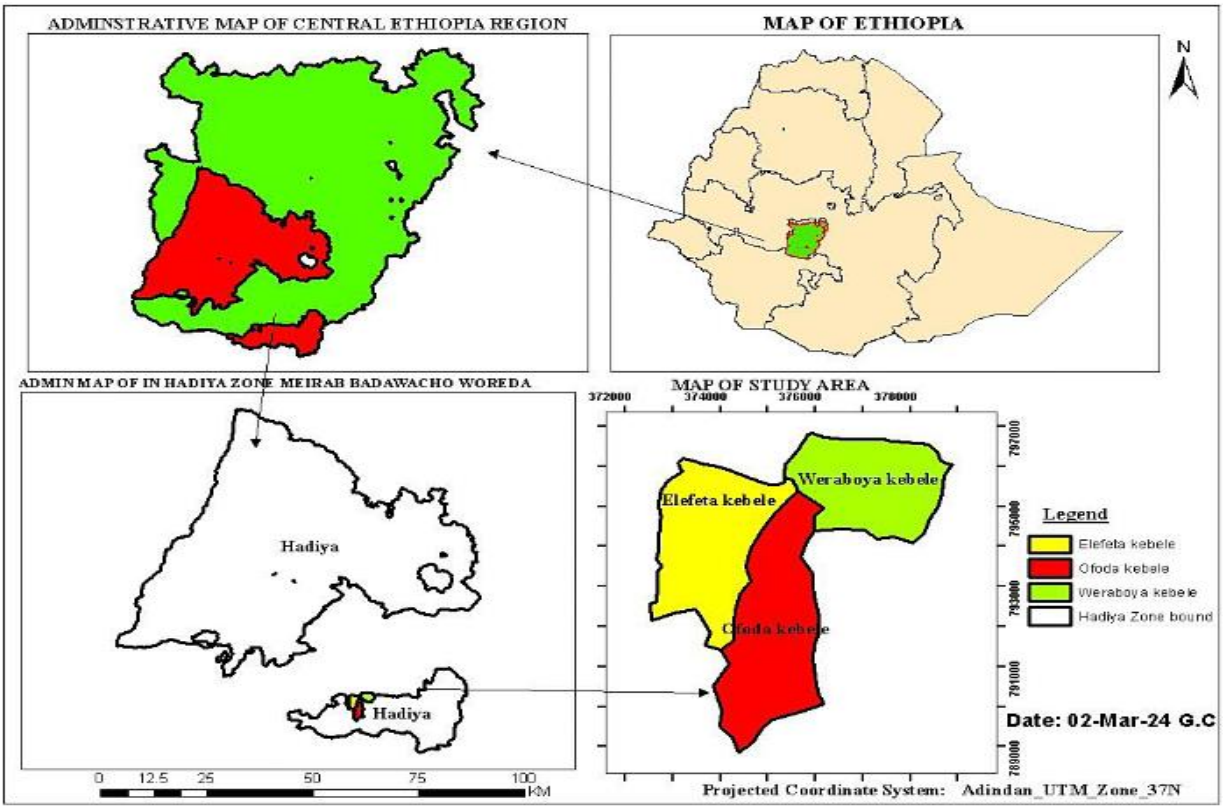

Figure 1. Map of study area

3.1.2 Topography, soil and climate conditions

The altitude of Merab Badawacho Woreda ranges from 1320 to 1980 meter above sea level. Totally there are 22 kebeles within Mirab Badawacho Woreda. Of which, most part is situated in *Kolla* that contains 15 kebeles (68%) and the rest 7 kebeles (32%) are situated in *Woinadega* agro-ecological zone (MBWANRDO, 2018). According to the MBWANRDO (2018), the common types of soil found in the Woreda is black (vertisoil), red brown basaltic (nitosoil), chromic vertisoil and in some parts of Woreda alluvial soil are common especially along the river bank of Angachicho and Ajacho rivers. The mean annual total rainfall is about 1250 mm and has average temperature of 21^0C. Rainfall is characterized by fluctuation in amount and periodicity from year to year in both agro-ecologies. The main rain season occurs from June to September while small rain season occurs from February to May. Extreme fluctuation in rain fall, both total and annual distribution, are the primary constraints for agriculture, resulting in food insecurity particularly under rain fed conditions (MBWANRDO, 2018).

3.1.3. Population and livelihood

Based on the census conducted by the Central Statistical Agency of Ethiopia (CSA, 2007), the Woreda has a total population of 120,000 of which 61,064 (50.9%) were females and 58,936 (49.1%) were males in which 14,400 are male headed and 2743 are female headed households. The average family size was 7. And, the majority of inhabitants are Hadiya ethnic groups with its distinct language and culture. The other ethnic groups living in the Woreda include Wolayta, Guraghe, Kambatta, Amhara and Oromo. The main language spoken in the woreda is Hadiyyissa. In terms of religion, the majority of the inhabitants were protestant (81.47%), Muslim (0.01%), Catholic (8.02%), and Ethiopian Orthodox Christianity (10.5%) (MBWFEDO, 2018).

3.1.4 Vegetation and land use

Agriculture serves as the means of livelihood to the majority of the people. It is characterized by traditional and mixed farming as it includes both crop and livestock production. The major growing crops in the study area includes wheat, barley, teff, sorghum, maize, irish potato, cassava; taro, sweet potato, haricot bean, vegetables and

enset. Livestock has also major roles in the farming system of Merab Badawacho Woreda. The major livestock in the area is cattle, goat, sheep and donkey (MBWANRDO, 2018).

3.2. Research Design

In order to achieve the intended objectives, cross-sectional survey research design was used. This is because the study calls for collecting data using questionnaires from households, key informant interviews and direct field observations regarding the widely grown neglected and underutilized root and tuber crops and their provisional ecosystem services and indigenous management practices in study area.

3.2.1. Sampling techniques

The preliminary survey was made from the beginning of April 2023 to June 2023 to assess the suitability of the study area for meeting the objective of the study. This survey was used to collect general information about the study area and identification of representatives sampling sites. Three representative sampling sites (Elefeta, Ofoda, Weraboya Kebeles) were selected using as purposive sampling technique.

3.2.2 Sample size determination

To determine the sample size, the formula of Yamane, (1967) was used

$$n = N/1+N(e)^2 \quad \text{.....Eq.(1)}$$

Where n is the sample size needed

N is the total number of households of the study area (1610) and e is the desired level of precision (in this case, e =5%) with the same unit of measure as the variance and e^2 is the variance of an attribute in the population.

Then the sample size (n) was calculated by employing equation 1

$$n = 1610/1+1610(0.05)^2 = 320$$

Accordingly, 320 households were sampled from the total household population of the three selected kebeles (1610) by using proportions of household population of the respective kebeles (Eq -3)

$$K = n * pi / N$$

Where n is the sample size selected from the three sample kebeles, in this case 320 household heads. Pi is the number of household population of the respective kebeles. N represents the total household of the three selected kebeles. K is sample household of each kebeles.

Based on this

Elefeta (n = 647 households), = 320 * 647 /1610 = 128 sample respondents.

Ofoda (n = 446 households), = 320 * 446 / 1610 = 89 sample respondents.

Weraboya (n = 517 households), = 320 * 517 / 1610 = 103 sample respondents.

A simple random sampling technique was used to select households from each kebele. The population size of the three kebeles was obtained from Merab Badawacho Agricultural and Rural Development Office and the managers of the respective kebeles.

The total number of households and the sample size from each kebele is summarized in Table 1

Table 1. Total number of households and the sample sizes

Sample kebeles	**Total households**	**Sample households**
Elefeta	647	128
Ofoda	446	89
Weraboya	517	103
Total	**1610**	**320**

3.3. Data Sources

The study used both primary and secondary data. The primary data were obtained through household survey, and interview with key informants and series of field observations. The secondary data were obtained from various published and unpublished sources of the governmental and the non-governmental organizations. Moreover, books, journals, internet sources, metrological data, research reports, archive and records were employed for acquiring necessary information.

3.4 Data Collection Instruments

Data collection instruments were used to collect both quantitative and qualitative data through questionnaires, key informant interview and field observation. The quantitative data was collected through survey questionnaire while qualitative data was collected through key informant interview and field observation.

3.4.1. Questionnaire survey

The data were collected from the sample household heads through the administration of of questionnaires. The household survey was conducted on different aspects: Indigenous management practices, and categories of root and tuber crops grown together in home-gardens. The interview covered size of home-garden, status of root and tuber crops, major root and tuber crop types grown widely, income sources, types of fertilizer and application, agricultural input usage, consumed crop, marketable crop, soil fertility management practices, factors that affect production of root and tuber crops, weed, pest and disease management practices, seed sowing method, source of planting materials, and crop productivity.

3.4.2. Key informant interviews

Interview was used as a data collecting instrument to get the views of key informants. The interview was used to cross-check the data collected through questionnaire and field observations. Interview questions were used to collect the data.

3.4.3. Direct field observation

Observation of the composition of widely cultivated root and tuber crops in home-gardens, their ecosystem services and indigenous management practices together with locally selected informants as well as with home-gardeners in each site during data collection. Field visits were conducted through walking along with informants discussing the indigenous and ecological knowledge. Direct field observation and guided walk targeted composition, uses and indigenous management practices of root and tuber crops and their uses. This method is supportive in order to get tangible information on traditional farming practice and enabled the researcher to identify the major neglected and underutilized root and tuber crops grown dominantly in the study area. Photo of different management practices and crop type, were taken during the field observations (Fig 2).

a. Hand weeding practices

b. Mixed cropping. C. Manure using practices in study area.

Figure 2. Photos of Indigenous management practices in study area

3.4.4 Data management and analysis

Both qualitative and quantitative data were analyzed. The qualitative data were analyzed partially during the process of data collection. The quantitative data were first summarized, tallied and coded, processed and were analyzed by means of Statistical Package for Social Sciences (SPSS) version 20 software. By means of descriptive statistics, the mean, range, frequencies, percentages, minimum as well as maximum values of variables were calculated.

4. RESULTS AND DISCUSSION

4.1. Demographic characteristics of sample households

Concerning the age of the households, about 43.13% of the household heads (aged between 36–45 years old, while 36.25% of the households aged above 46 years old, 20.6% aged between 25 and 36 years old. Most of the households were male-headed (83.44%) and were married. As to the educational level, 33.4% of the households attended primary education, while 16.56% were illiterate (Table 2). This indicates that the majority of the households in study area were educated.

Regarding home-garden size, 62.5% of the households had 0.5 hectare and 28.1% had 0.25 hectare and only 9.3% had 1 hectare and above. The mean home-garden size of land was 0.58 hectare, indicating shortage of home-garden size in study area. Households and key informants informed that home-garden size declined due to high population density and family size. Similar results were reported (Genash Amada, 2014; Amare Seifu *et al*., 2019). About 73.4% of the households had a family size that ranged between 2 and 5 and 13.4% had 6-7 and 13.1% had 8 - 10 members (Table 2). Most households had a family size ranging between 2 - 5 members. Family size positively influenced the productivity of root and tuber crops, because large family size provides more labor force, which would enable households to accomplish various cultivation tasks. Similarly, Getachew Belachew (2014) reported that households with large family size had more labor forces that engage in agricultural production, such as harvesting practices, pest and disease management practices.

Table 2. Demographic characteristics of sampled households.

Characteristic	Household heads	Number	Present
Gender	Male	267	83.44
	Female	53	16.56
	Total	**320**	**100**
Age	25 – 35	66	20.62
	36 – 45	138	43.13
	> 46	116	36.25
	Total	320	**100**
Educational status	Illiterate	53	16.56
	Primary	107	33.44
	Secondary	43	13.44
	college diploma and above	42	13.12
	non formal	25	23.44
	Total	**320**	**100**
Marital status	Single	43	13.44
	Married	213	66.56
	Divorced	32	10
	Widowed	32	10
	Total	**320**	**100**
Total family	2-5	235	73.44
	6-7	43	13.44
	8-10	42	13.12
	Total	320	**100**
Home-garden size	1 hectare and above	30	9.3
	0.5 hectare and above	200	62.5
	0.25 hectare	90	28.1
	Total	**320**	**100**

4.2. Crops, livestock and income

Most of the households grew root and tuber crops in their home-gardens (Table 3). A large number of households, greater than 80%, widely cultivated sweet potato (*Ipomoea batatas*), Taro (*Colocasia esculenta*), Enset (*Ensete ventricosum*) and yam (*Dioscorea spp*.). About 13.44% cultivated Yam (*Dioscorea spp*.), cassava (*Manihote sculenta*) and sweet potato (*Ipomea batatas*), Ethiopian potato (*Plectranthus edulis)*, ginger (*Zingiber officinale*), and onion (*Allium cepa*). Amare Seifu *et al.* (2019) reported in Gedio zone southern Ethiopia that sweet potato, enset and yams were widely grown in home-gardens. Most of the households (69.69%) cultivated root and tuber crops in home-garden only mainly to manage and protect them from wild animals. Similarly, Jemal and Callo-Concha (2017) reported that root and tuber crops were grown in home-gardens for similar reasons. About 16.56% and 13.75% of the households cultivated root and tuber crops in extended home-gardens and typical farm-lands, respectively. Similarly, Yirefu Tefera *et al.* (2019) found out that households cultivate root and tuber crops in both home-gardens and field as management strategies in home gardening activities.

Additionally, all households rar livestock. Most of the households (62%) had cow, oxen, chickens, donkey and goats and 37.5% of the households had donkeys, horses, sheep and goats (Table 3). Agriculture was the major source of income for the households. In this regard, about 80% of the households generated income from livestock farming. They kept livestock for various purposes such as for food (source of egg, milk and meat), means of transport, animal manner and organic fertilizer, and source of cash for urgent needs. Livestock was also considered as a measure of wealth status.

Table 3. Root and tuber crops, livestock and income

No	Questions	Options	Frequency	Percent
1.	What type of major root and tuber crops do you produce in your home-garden?	Enset, sweet potato, Ethiopian potato, cassava, taro, other specify	256	80
		Sweet potato, yam, potato, Enset	21	6.56
		Yam, cassava, sweet potato	43	13.44
		Total	**320**	**100**
2	What types of farmland do you use to grow root and tuber crops?	Home-garden only	223	69.69
		Extended homegarden	53	16.56
		Typical farm land	44	13.75
		Total	**320**	**100**
3	Does your household have livestock?	Yes	320	100
		No	0	0.0
		Total	**320**	**100**
4	What types of livestock do you keep?	Oxen, cows, chickens, goats sheep	200	62
		Donkey, horse	120	37.5
		Total	**320**	**100**
5	What is the major sources of your income?	Agriculture	320	100
		Other	0	0.0
		Total	**320**	**100**
6	Do you get income from any other sources outside agriculture?	Yes	320	100
		No	0	0.0
		Total	**320**	**100**
7	If your answer is **''Yes''** for question number 6 what are the sources of income?	Trading	64	20
		Livestock farming	256	80.0
		Total	**320**	**100**

4.3. Provision of ecosystem services of root and tuber crops

Root and tuber crops were used for traditional food, income generation, animal feed, traditional medicine and food supplement. Negash Geleta, (2019) and Eden Genetu *et al*. (2023) reported that millions of smallholder farmers in Ethiopia used root and tuber crops as their major or supplementary food and source of cash. The majority of the households (56.5%) used root and tuber crops for traditional medicine to treat stomachache, kidney infection, common cold and fungal disease. Similarly, Eden Genetu *et al*. (2023) reported that most households used root and tuber crops for traditional medicinal purposes in Gedio zone southern Ethiopia. About 33.4% of the households used root and tuber crops for animal feed (Table 4). The majority of households used sweet potato, taro, enset, yam and Ethiopian potato for food and animal feed. Moreover, some of the households used root and tuber crops for income, food flavoring and feed. Similar result was reported by Eden Genetu *et al.* (2023) that root and tuber crops were used for income generation, food and animal feed.

Table 4. Potential uses of root and tuber crops

No	Question	Answer	Frequency	Percent
1	Do you use root and tuber crops for food?	Yes	320	100
		No	0	0
		Total	**320**	**100**
2	What are the other uses of root and tuber crops?	Animal feed	107	33.44
		Medicinal purpose	181	56.56
		Industrial raw	32	10
		Total	**320**	**100**
3	If "yes" for which disease treatment you use these crops?	Stomach ache	100	31.25
		Kidney infection	53	16.56
		Common cold	60	18.75
		Fungal disease	107	33.44
		Total	**320**	**100**
4	Do you use root and tuber crops as income Source	Yes	267	83.44
		No	53	16.56
		Total	**120**	**100**
5	Amount of money sold per year from root tuber crops	Min	Mean(SD)	Max
		1000	30500 birr	60,000

Most of the households mentioned that root and tuber crops were adaptable staples to address food security, and yield more food per unit area of farmland. Furthermore, the majority of the households used root and tuber crops for food consumption (Table 5). In this regard, most of the households (86.5%) used *Ensete ventercosum* for food and about (13.4%) used it for marketing. Enset was used to make different cultural dishes and other materials having multi-services and fodder for the livestock. Especially its leaves are important to livestock feed. Enset is commonly consumed in four forms and named in local language as Hadiyissa wassa (bread form), Bashanko'o (which is made from Enset and potato and cabbage), Amicho (boiled enset corm) and Atakana (which is made from Enset and milk). It is a multipurpose crop in the south and south western part of Ethiopia, and it is a stable food for more than 20 million people in Ethiopia (Zerihun Yemataw *et al*., 2014, Amare Seifu and Daniel Fitamo, 2016). Enset was mainly used for human food and livestock feed, although every part of the plant can be used in

different ways. The pseudo-stem, corm of enset, is the most important source of food for human, whereas the whole part of the plant except the root is used to feed livestock. It was also used as medicine to treat both human and livestock ailments. Semerdin Yimar and Tsegaye Babege (2018) reported that Enset is one of the drought tolerant food security crops, where it supplements human calorie requirements of around 20 million people in Ethiopia. Enset ranked first in terms of consumption when compared to other neglected and underutilized root and tuber crops such as Taro, sweet potato, Ethiopian potato (Fig. 3). Taro locally "Godare" is the second grown and forth consumable root and tuber crop in study area compared to other neglected and underutilized root and tuber crops. About 66% of the households used Taro for consumption and 34% for marketing. This implied that Taro is forth consumable and second marketable root and tuber crop in study area. This indicates that in study area most of the households used Taro locally "Godare" for consumption. Similarly Yared Dagn *et al*. (2014) reported that Taro was cultivated by smallholder farmers and supported the livelihood of the population next to Enset. The majority of households (70%) used sweet potato for consumption and only 30% households used sweet potato for marketing. About 50% of the households used Discorea species for consumption and 50% of households used for marketing. Similarly Merknehi Bekele *et al.* (2021) reported that yam was cultivated for household food supply, and income generation.

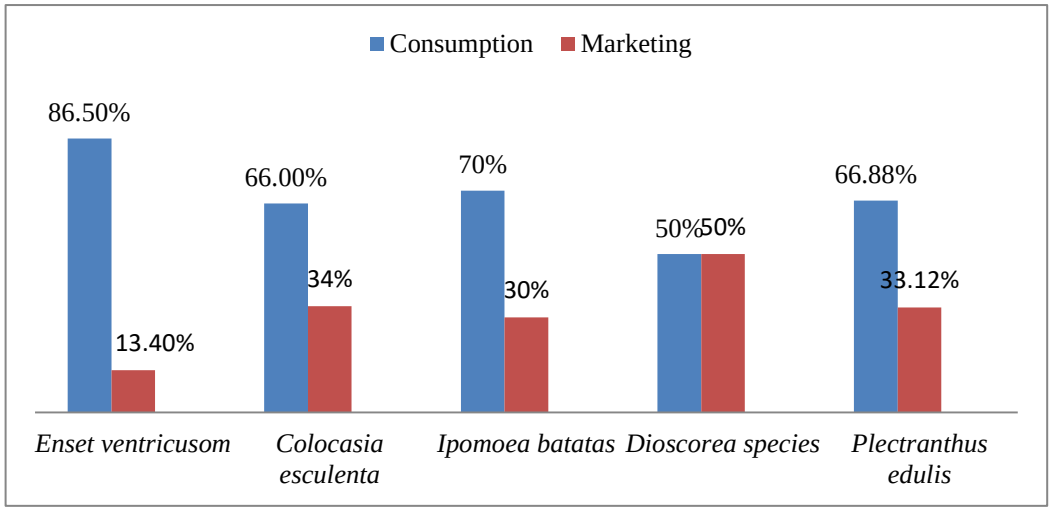

Figure 3. Socio-economic importance of root and tuber crops

4.4. Indigenous management practices of root and tuber crops

The households practiced different types of management practices of root and tuber crops in home-gardens. Some of the major traditional management practices include tillage system, cultivation system, weed management system, pest management system, fertilizer application methods, seed storage system and sowing methods. About 78.1% of the households practiced manual tillage and 12.5 % used both oxen and manual tillage practices (Table 5). Most of the households practiced manual tillage because they held small land sizes. The households also practiced mixed and mono-cropping practices. The majority of households practiced mixed cropping. They ploughed home-gardens with manual techniques by using local traditional tools.

Manual tillage is more comfortable than oxen tillage to manage root and tuber crops. The majority of households used manual tillage for preparation of seed bed. Manual tillage is cost effective and environmentally friendly in managing farm land than oxen traction. Similarly (Sime *et al*, 2015) reported that minimum tillage improved farm productivity and is also an opinion for farmers lacking oxen for plowing. The result was supported by Alemtsehay Tsegaye *et al*, (2018) that manual tillage was environmentally acceptable than animal and machine tillage. Because minimum tillage can minimize soil degradation and benefit farmers with poor access to draft power or female headed households constrained with labour for ploughing. Households practiced minimum tillage because it helps farmers lowering soil erosion, improving soil infiltration,and maintaining soil moisture.

Apart from that, households practiced different techniques to store root and tuber crops. About 86.5% of the households reported that they store the seed or corm of root and tuber crops in cool or under shade. Whereas 13.4% stored the root and tuber crops in dry or in the house dry places. Similarly Tikai and Kama (2010) reported that farmers' stored taro and other root and tuber crops in cool place (shade place).

4.4.1 Indigenous weed, pest and disease management practices.

Households undertook many activities to control the various pests and disease that affected the crops to enhance the yield of the root and tuber crops (Table 5). Among the methods, households used improved seeds that were resistant to disease, increased the frequency of fallow land, and used mainly mixed cropping, crop rotation and shifting cultivation similar result was reported by Ephrem Guchi (2015). Manual method of weeding was widely used. In the study areas, households used different indigenous weed, pest and disease management practices. About 85.9% of the households used manual methods to control weed, pest and disease. They practiced hand weeding, removal of diseased plants, selection of planting material and intercropping. Whereas about 9.3%, 4.6% sprayed pesticides to control weed and pest respectively. The overwhelming majority of the households (93.4%) also used manual weeding techniques in mixed cropping of root and tuber crops. Manual method is physical method, which involves pulling and mowing weeds by hands and is preferred by the majority of the households who practices mixed cultivation of neglected and underutilized root and tuber crops.

Table 5. Indigenous management practices of root and tuber crops

No	Question	Answer	Frequency	Percent
1	What is the most common tillage you practice for land preparation?	Oxen plough	30	9.3
		Manual	250	78.1
		Both	40	12.5
		Total	**320**	**100**
2	What is the most commonly used weed management practices on your home-garden?	manual	275	85.9
		herbicide	30	9.3
		other	15	4.6
		Total	**320**	**100**
3	What is the most commonly used pest management practices on your home-garden?	manual	275	85.9
		Pesticide	25	7.8
		Other	20	6.25
		Total	**320**	**100**
4	Where do you store seed of neglected and underutilized root and tuber crops?	Gene	0	0
		Cool place	277	86.56
		Drysoil	43	13.44
		Total	**320**	**100**
5	Weed in multiple cropping system	manual	299	93.44
		herbicide	21	6.56
		Total	**320**	**100**

4.4.2. Indigenous soil fertility management practices

Households used different methods to increase soil fertility (Table 6). Among this agronomic soil fertility management practice was dominant. This technique improves soil structure by improving organic matter in the soil to stable soil moisture. This method include soil fertility management practices like use of manure, crop rotation, fallowing, intercropping and mulching (Musher and kedru, 2012). Out of the households, about 98.4% of them used manure to increase soil fertility, while 1.5% of the households did not utilize manure as the measure of soil fertility (Table 6). This is due to lack of livestock rather than less perception towards fertility enhancing capability. However, such households sometimes take manure from others having livestock. Abera Ogato (2006) indicated that households lacking livestock get manure through borrowing system. The field survey, observation and key informants interview showed that rearing livestock was for utilization of manure to increase home-garden soil fertility for root and tuber crops production, and income generation. About, 97.1%, 91.5%, 87.5% of the households practiced crop rotation, mixed cropping and fallow land, respectively to increase soil fertility in study area (Table 6).

Table 6. Indigenous soil fertility management practices

Indigenous management practices	Alternatives	Frequency	Present
Mulching	Yes	250	78.1
	No	70	21.8
Use of manure	Yes	315	98.4
	No	5	1.5
Fallow land	Yes	280	87.5
	No	40	12.5
mixed cropping	Yes	293	91.5
	No	27	8.4
Crop rotation	Yes	311	97.1
	No	9	2.8
Agro forestry	Yes	260	81.2
	No	60	18.7

4.4.3 Distribution of neglected and underutilized root and tuber crops

About 91.5% of the households indicated that planting and cultivating root and tuber crops in home-garden increased the yield of root and tuber crops, eased the use of animal manure during cultivation, protected from wild animals and pests, and decreased labor-force (Table 7). About 3.1% of the households reported that they cultivated root and tuber crops in both home-garden and farmland, and 5.3% cultivated only in farmland. Key informants witnessed that there were no newly introduced root and tuber crops although there were some wild relatives. In terms of wild relative of root and tuber crops, 16.6% of the households incorporated the wild relative into home-gardening, while 83.4% did not cultivate wild relative root and tuber crops (Table 7). In addition,

the key informants reported that there were differences between cultivated and wild relative of root and tuber crops. The majority of the households recognize these differences based on different factors such as their yield, taste, growth rate, size and the like**.** similar result were reported by Amare Seifu *et al.* (2019) in Gedio zone southern Ethiopia.

Table 7. Distribution of root and tuber crops

No	Question	Category	Frequency	%
1	Where do you produce root and tuber crops?	Home-garden	293	91.5
		Farm-land	17	5.31
		Both	10	3.1
		Total	**320**	**100**
2	Is there neglected and underutilized root and tuber crops in your home-gardens with wild relatives?	Yes	53	16.56
		No	267	83.44
		Total	**320**	**100**
3	If "**Yes**" how do you differentiate between wild relatives and cultivated ones?	Product size	109	34.06
		Growth rate	200	62.5
		Taste	11	3.44
		Total	**320**	**100**

4.4.4 Status of root and tuber crops production

The majority of households reported that cultivation of root and tuber crops declined from time to time, which is similar with earlier studies (Singing and Mababu, 2015; Kusse Kutoya, 2021). About 85% of the households reported that production of root and tuber crops declined, 9% reported that the production of root and tuber crops increased and 6% of the households reported

that there was no change on the production of root and tuber crops (Fig. 4). Increasing interest to engage in the production other cereal crops was one of the reasons for the declining of root and tuber crops production. This attributed to population growth and shortage of land which led them to food shortage and forced to grow short season cereal crops like wheat, Teff, maize, etc. Lack of improved seed, weed, pests and disease were the main factors that decreased the production of root and tuber crops, which agree with findings from previous studies (Birhanu Amare *et al*., 2014; Yimar and Babege, 2018). The Woreda is known for cultivating maize, Teff, wheat, cash crops and other cereal crops addition to root and tuber crops. Mixed cropping and crop rotation were the best method they used to reduce weed, pest and disease and increase the yield of root and tuber crops.

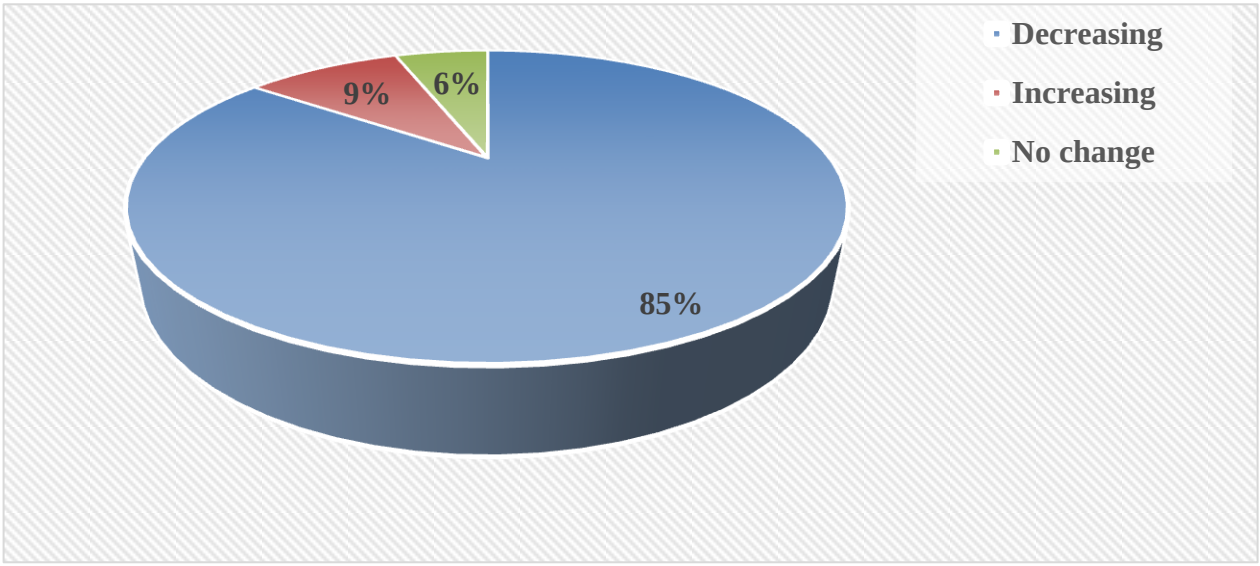

Figure 4. Trend or status of root and tuber crops cultivation.

4.4.5 Cultivation system of root and tuber crops

Almost all of the households cultivated root and tuber crops. Of these, 66.6% of them reported that mixed cropping was one of the most frequently used indigenous methods of maintaining soil fertility for the root and tuber crops. They also reported that they practice mixed/intercropping systems and grow two or more crops on the same farmland in the same cropping season (Table 8). This is to cope up with the diminishing land-holding size. About 83.4% practiced mixed cropping. Associated species that grew with root and tuber crops were coffee, Enset, maize and avocado. Besides, most of the

households reported that cultivation of those root and tuber crops with other crop species have advantages. The majority of the households (83.4%) mentioned the benefits of mixed/intercropping of root and tuber crops to be increase in soil fertility and increase in yield of crops per unit land. About 16.6% of the households reported that mixed/intercropping save time for the management practices of crops (Table 8). Amare Seifu *et al.* (2019) reported that mixed and intercropping increased soil fertility and increased the yield of crops in small area in Gedio zone southern Ethiopia. Similarly, Tofiga (2003) described mixed cropping as the growing two or more crops simultaneously on the same piece of land with or without distinct row management. Mixed cropping systems created favorable condition for the soil, water, nutrients and provide excellent environmental conservation and sustainability and to maintain soil fertility.

Table 8. Cultivation system of root and tuber crops

No	Question	Category	Frequency	%
1	Do the neglected and underutilized root and tuber crops associate with other crops?	Yes	280	87.5
		No	40	12.5
2	If "**Yes**" which of the following crops associate with the neglected and underutilized root and tuber crops?	Coffee, Enset, Maize and avocado	267	83.4
		Ensete, Avocado and Mango	53	16.5
3	Which type of cultivation system do you mostly practice on your home-garden?	Mono cropping	107	33.4
		Mixed cropping	213	66.6
4	If you use multiple cropping, why do you practice multiple croppi ng systems?	Productivity	267	83.44
		Soil fertility	53	16.56

4.4.6 Input usage

Households managed soil fertility through applying organic, inorganic and mixture of organic and inorganic fertilizers. Both organic and inorganic fertilizers were used to increase soil fertility. Households indicated that when soil fertility increases root and tuber crop yield also increases.

About 66.5% of the households used only organic fertilizer to increase soil fertility. Only 10% of them used chemical fertilizers and 23.4% of the households used mixture of organic and inorganic fertilizer to increase root and tuber crops yield (Table 9). This shows that most of the households used organic fertilizers in root and tuber crops management production. Findings from previous studies indicated that the use of organic fertilizers, specifically animal manure, improves soil quality and increases crop yield. Households had different sources of organic fertilizers. About 56.6% got organic fertilizers from animal manure. This implied that animal manure is the main source of organic fertilizer in study area. Livetsock has strong association with improving production and management practices of neglected and underutilized root and tuber crops in the study areas. Next to livestock manure, 26.5% of the households used organic fertilizer in the form of compost, 16.5% used household wastes as source of organic fertilizers. The key informants witnessed that root and tuber crops are mostly cultivated in home-garden areas and do not need external inputs.

Additionally, all of the households used purchased inputs. In accordance, the majority of the households purchased improved seed. A considerable number of households also used hired labor. A few households purchased chemical fertilizers (Table 9).

Table 9. Agricultural input usage

No	Question	Answer	Frequency	Percent
1	What is the most commonly used fertilizers type in home-garden?	Chemical fertilizer	32	10.0
		Organic fertilizer	213	66.5
		Mixed of both organic and chemical fertilizer	75	23.4
		Total	**320**	**100**
2	Which type of organic fertilizer do you use mostly?	Animal manure	181	56.6
		Compost	75	26.53
		Others	1	0.31
		Household waste	53	16.53
		Total	**320**	**100**
3	Do you use purchased inputs?	Yes	320	100.0
		No	0	0.0
		Total	**320**	**100%**
4	What type of purchased inputs do you use?	Improved seed	167	52.19
		Hired labor	135	42.19
		Chemical fertilizer	18	5.62
		Total	**120**	**100**

4.4.7 Planting season and Source of planting materials of the root and tuber crops

Yam and sweet potato were cultivated on an annual cycle of planting that commences at the onset of the dry season. Whereas, the others Taro /godare, Ethiopian dinich and Enset were cultivated in summary season. The majority of the households planted root and tuber crops in October; whereas few households planted root and tuber crops in January. There is no formal seed supply system for root and tuber crops in the study area nor do farmers specialize in the production of crops planting-materials.

The majority of the households got planting materials of the root and tuber crops from their own home-garden. In accordance, about 62.5% of the households got the planting materials from own saving from previous harvest. Similarly, Singing and Mababu, (2015), traditionally farmers appreciate additional agronomic benefits such as the possibility of using planting material from own fields. About 21.8% of the households got planting materials from exchanges with neighbors. Only 9.3% and 6.3% of the households got planting materials from local agricultural office and local markets, respectively (Fig. 5). Similarly, Muluneh Tamiru *et al.* (2015) reported that the farmers in Wolaita zone southern Ethiopia mostly rely on their own planting materials saved from the previous cropping season.

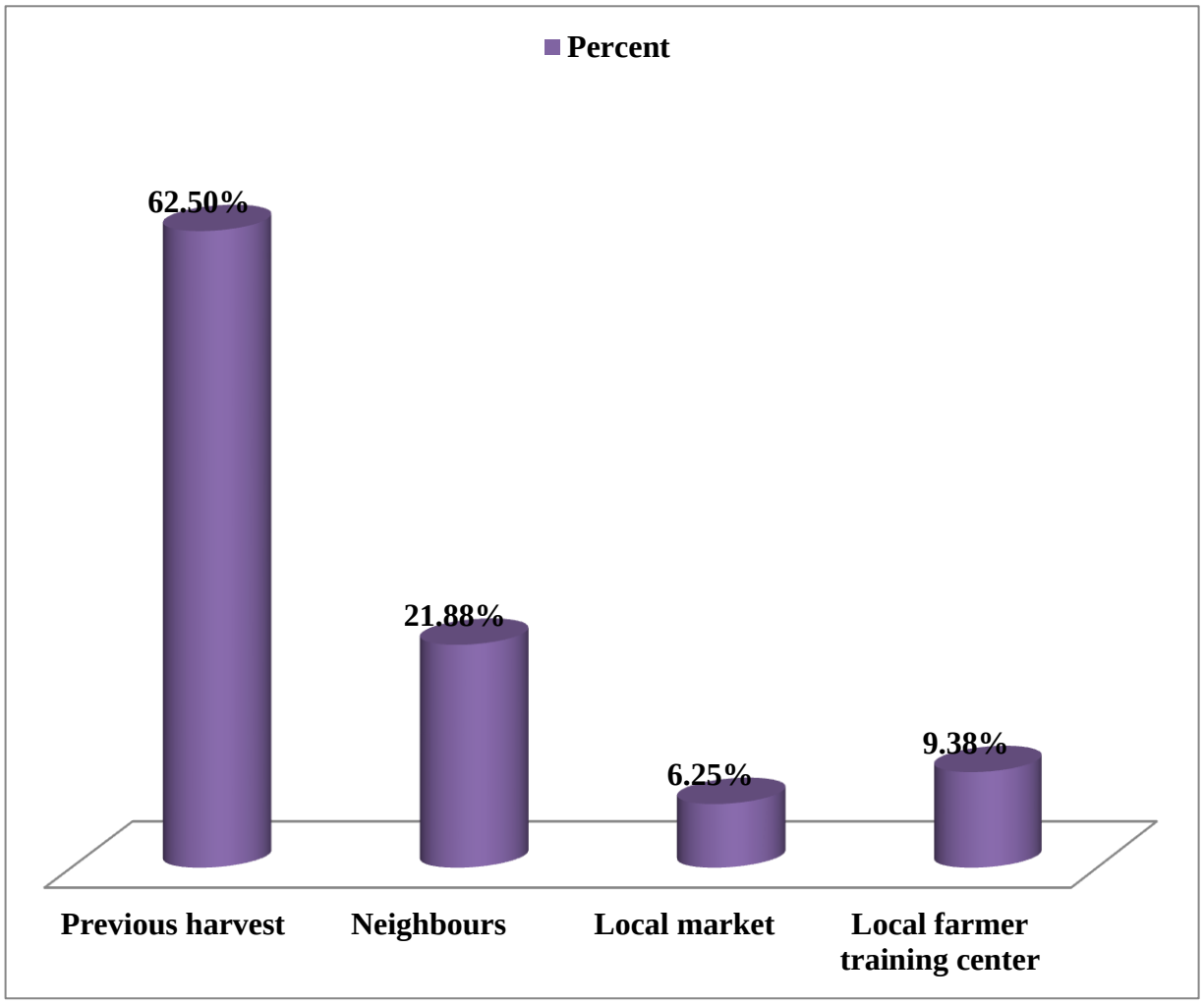

Figure 5. Sources of planting materials of NURTCs

4.4.8 Factors that affect the management practices of root and tuber crops

According to the majority of the households (31.2%), shortage of land was one of the most important factors constraining the production and management practices of root and tuber crops. About 28.1% of households mentioned that pest and disease affected the production and management practices of root and tuber crops (Fig. 6). This shows that pests and diseases are the major constraint to the production of root and tuber sector, after shortage of land. Similarly, CSA (2016) reported that pests and disease affect the production of root and tuber crops. Still, about 21.8% and 12.1% of the households respectively cited that lack of improved seed and shortage of rain affected the management practices and production of root and tuber crops (Fig. 6). Similarly, Semerdin Yimer and Tsegaye Babege (2018) reported that shortage of good quality planting material and inability to control biotic factors (disease and pest) were the primary limiting factor to the production and management practices of root and tuber crops.

Although root and tuber crops provide multiple services to local communities, they have been overlooked by researchers and policy makers (EIAR, 2015; Helen Teshome, 2016). Moreover, the contribution of root and tuber crops to the national gross domestic product is not well known. There are only few reports regarding root and tuber crops production in Ethiopia. Inadequate storage, transportation and marketing facilities are the other constraints of root and tuber crops production. Key informants witnessed that lack of improved seed soundly affected the production of root and tuber crops. Similarly, Birhanu Amare *et al.* (2014) reported that lack of improved root and tuber crops varieties suitable for different agro-ecologies and resistant to insect pests were some of the factors that hinder the crop expansion.

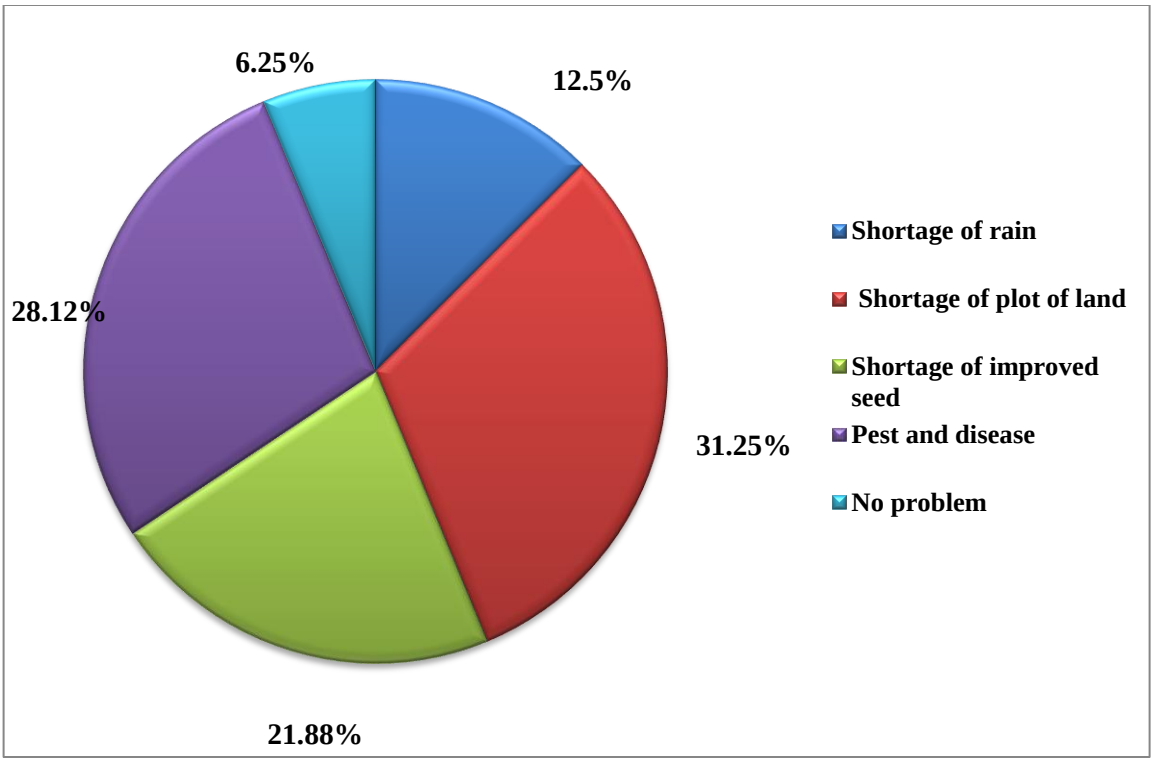

Figure 6. Major factors affecting the production and management practices of root and tuber crops

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The root and tuber crops had high yielding potential per unit area and provide multiple provisioning ecosystem services including source of food, income, feed and traditional medicine. The most widely used root and tuber crops in terms of food, income and traditional medicine were Enset *(Ensete ventricosum* (Welw.) Cheesman), Taro *(Colocasia esculenta* (L.) Schott), Sweet potato *(Ipomoea batatas* (L.) Lam.), Ethiopian potato *(Plectranthus edulis* (Vatke) Agnew) and Yams (*Dioscorea spp.).* Households mostly practiced manual methods to control weed, pest and disease such as hand weeding, removal of diseased plants, selection of planting material and mixed cropping. Households used different indigenous soil fertility management mechanisms such as livestock manure, crop rotation, fallowing land and mixed cropping. However, the production of root and tuber crops declined mainly due to an increasing engagement in the production of other cereal crops of short season cereal crops. The other factors contributing to the decline were lack of improved seed, weed, pests and disease. The potential uses of neglected and underutilized root and tuber crops are for food security, traditional medicine and income generation. However, their uses have not been fully exploited. Root and tuber crops are among the neglected and underutilized climate resilient food security crops in Ethiopia requiring an immense policy focus. Moreover, the cereal-centered policy so far is unable to reduce rural food insecurity and in fact this problem even got worse and worse over time. Therefore, promotion of neglected and underutilized root and tuber crops could play a crucial role in improving the food and nutrition security of the fast growing population of the country

5.2. Recommendations.

Depending on the result of this finding the following recommendations were forwarded.

- High focus should be taken to keep the present root and tuber crops in the study area.
- Taking into account the roles of root and tuber crops in traditional agriculture system and people's culture, better attention need to be given by all actors to fully utilize in daily diet and ensuring food security.
- High attention should be taken in transferring of indigenous knowledge of weed, pest and disease management in to the younger generation.
- Agricultural agents and other stakeholders should be given a continuous training for local farmers on how to cultivate, conserve NURTCs from different constraints.
- Thus, it is essential to reorient this policy by the upcoming plan. This will substantially contribute to improve the livelihoods of resource poor rural people's in operating under different poor livelihood conditions.

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7. APPENDICES

RESEARCH QUESTIONNAIRE

APPENDIX I. SEMI- STRUCTURED INTERVIEW QUESTIONS ADMINISTRATED TO SAMPLE HOUSEHOLDS.

HAWASSA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

DEPARTMENT OF BIOLOGY

DEAR RESPONDENT:

This questionnaire for interview is designed to collect data for the Msc thesis research entitled **"Neglected and underutilized root and tuber crops, provisioning ecosystem services, and Traditional management practices," in Merab Badawacho Woreda, Hadiya Zone, Central Ethiopia.**

The questionnaire is prepared only to collect information related to management practices and ecosystem services of neglected and underutilized root and tuber crops and associated indigenous knowledge of community of the district and the data collected is also use for this study. therefore, would you please, feel free and give your generous responses to the questions.

Thank,you in advance for your time and valuable responses.

General responses about the respondent

Date of data collection_____

Name of the respondent_____

Name of the enumenator_____

Name of the kebele/village._____

A. HOUSEHOLDS CHARACTERISTICS

1. sex of the respondent A, male. B, female.

2. Age of the respondent (incompleted years)_____

3. What is your highest level of education?

A. Illiterate

B. primary education C. secondary education D. certificate

Diploma and above

E. non formal/adult education

4. Martial status A, married. B, Divorced. C, Widowed D, single.

5. Total family size_____

¡, a no of children_____a no of adults_____

¡¡, anumber of dependents a no of independents

6. Total land size_____

7. Home-garden size

B. Types of root and tuber crops, Income and wealth

1. What types of major neglected and underutilized root and tuber crops do you produce? (Underline that apply)

A. Enset, Sweetpotato, Potato, cassava, Taro, Otherspecify____

B. Sweet potato, Yam, Potato, Others.

C. Enset, Yam, cassava, Mhinot esculenta, Sweet potato

Other specify_____

2. Select the types of farmland cultivated by the household and fill their respective size (ha)

No	Types of farm land	Size(ha)
¡	Home-garden only	
¡¡	Extended home garden	
¡¡¡	Typical farm land	
¡v	Shared crop land	
V	Others	

3. Does your house hold have livestock? A. Yes B. No

4. If yes specify the number of each type listed below

Oxen_____cows_____calves_____cheifers_____

Bulls_____Goats_____Sheep_____Chickens_____

Donkeys_____Horses_____Mules_____

5. What are the major Sources of your income?

6. Do you get income from any other sources? Out side agriculture?

7. If"yes"sources of income___average annual income (inbirr)___

C. Distribution of root and tuber crops.

1. where you produce root and tuber crops?

A. home-garden B. farmland C. both home-garden and farmland

2. Is there neglected andunderutilized root and tuber crops have wild relatives?

A. yes B. No

3. If “yes” how you differentiate wild relatives from cultivated? List the factors used to differentiate cultivated from wild relatives_____

_____

_____

D. Cultivation system of root and tuber crops

1. List the most commonly grown consumed and marketable neglected and underutilized root and tuber crops.

No	Most commonly grown root and tuber crops	Consumed	Marketable
1			
2			
3			
4			

2. Do the neglected and underutilized root and tuber crops associate with other crops?

A. Yes. B. No

3. If "Yes" which of the following crops associate with neglected andunderutilized root and tuber crops?

A. coffee arabica, chatae dulis ,persea americana B. maize ,Musa paradisica, coffee ar abica C. Other specify_____

4. Which type of cultivation system do you mostly practice on your home-garden?

A. Mono cropping B. Multiple cropping

5. If you use mixed cropping why you practice mixed cropping system?

6. What are the benefits of mixed cropping?

E. Input usage

1. What is the most commonly used fertilizers type on your farm?

A. Chemical fertilizer B. Organic fertilizer

C. Mixture of organic and chemical fertilizers

2. If you use organic fertilizer which type of organic fertilizer do you use most?

A. Animal Manure B. Compost C. Household waste D. others specify

3. Do you use purchased inputs in your agricultural activity?

A. Yes B. No

4. If "yes" Which of the following inputs you use?

A. Improved seed B. Chemical fertilizer herbs, pesticides

C. hired labor D. Others specify_____

F. Potential uses of neglected and underutilized root and tuber crops.

1. Do you use neglected and underutilized root and tuber crops for food?

A. Yes B. No

2. What are the other uses of neglected and underutilized root and tuber crops?

3. Do you use neglected underutilized root and tuber crops for medicine purpose? A. Yes B. No

4. If "yes" for which disease treatment you use these crops?

5. List neglected and underutilized root and tuber crops and there medicinal uses.

6. Do you use neglected and underutilized root and tuber crops as income Source?

A. yes B. No

7. If "yes" how much birr you get by selling the neglected and underutilized root and tuber crops?

8. What is average (mean) estimated amount of many sell per year from neglected and underutilized root and tuber crops_____?

G. INDIGENOUS MANAGEMENT PRACTICES OF NEGLECTED AND UNDERUTILIZED ROOT AND TUBER CROPS

1. The most common tillage you practice for land preparations

A. Manual B. oxen plough C. Both D. Other specify.

2. What are the most commonly used weed management practices on your farm?

A. Manual B. Herbicide C. Oxen plough D. Other specify_____

3. What are the most commonly used pest management practices on your farm?

A. Manual B. Pesticides C. other traditional methods specify_____

4. What is the most commonly used chemical fertilizer application method on your farm?

A. broadcasting B. Row application C. Spot application

D. other specify_____

5. What is the most commonly used seed sowing method on your farm?

A. broadcasting B. Row application C. Spot application D. other specify___

6. Where you store seed of neglected and underutilized root and tuber crops

A. Gene bank B. Cool place (Shed places) C. other specify____

7. List the names of crops grown with neglected and underutilized root and tuber crops_____
_____
_____
_____
_____

8. How do you control weed in multiple cropping system?

A. By applying herbicide B. Manual removals C. leave without removing weed D. Other-

specify_____
_____

9. In your home-garden root and tuber crops increasing or decreasing?

A. Increasing. B. Decreasing C. No change

Appendix II

Semi-structure interview questions and administered for both sample households and key informants.

1. Which cropping system is good for increasing productivity of neglected and underutilized root and tuber crops?

A. mono cropping B. multiple cropping

2. Which cropping system is best to control weed and pest?

A. mono cropping B. mixed cropping

3. How do you cultivate and maintain soil fertility?

A. Mixed cropping B. Mono cropping

4. Where you store neglected and underutilized root and tuber crops?

5. What are the factors that affect neglected and underutilized root and tuber crops production?

6. How do you manage pests, disease other factors that affect root and tuber crops?

7. from where you get planting materials of root and tuber crops?

A. Saved from previous harvests B. Exchanged with neighbors C. local agricultural office D. local markets

8. Is there new introduced root and tuber crops in your home-garden?

9. Is there lost one in your farm?

10. how can you compare root and tuber crops cultivation in the past years and in the current in your home-garden?

11. Currently root and tuber crops increasing or decreasing in your home-garden?

12. How do you mange soil fertility by using your indigenous knowledge

Appendix III

Different Photographs of root and tuber crops and their management practices in study area.

a. Traditional intercropping practices of root and tuber crops


b. Indigenous weeding practices of root and tuber crops

c. Mixed cropping practices of taro with Ethiopian potato and Indigenous planting practices of sweet potato