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REVIEW ON ADOPTION AND IMPACT OF IMPROVED AGRICULTURAL TECHNOLOGIES ON FARM INCOME IN ETHIOPIA

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ABSTRACT

The importance of agricultural technology in enhancing production and productivity can be realized when yield increasing technologies are widely been used and diffused in the community. Based on this logic, this study examines the adoption and impact of improved agricultural technologies on farmers' income in Ethiopia. One of how farm productivity can be increased is through the introduction and dissemination of improved agricultural technologies to farmers. The objective of this review was to assess the factors affecting the adoption and impact of improved agricultural technologies. Various socio-economic factors, institutional and the characteristics of the farmers were those factors affecting the adoption and intensity of agricultural new technologies. The adoption of livestock technologies was highly influenced by location factors as well as agro-ecological factors.

Keywords: Adoption; agricultural technologies; intensity; impact; dissemination.

1. INTRODUCTION

The importance of agricultural technology adoption in ending poverty and food insecurity has been well discussed by Doss & Morris, [1]; Mendola, [2] and Becerril & Abdulai, [3]. According to Ajayi, Franzel, Kuntashula, & Kwesiga, [4] and Gemeda, [5] in developing countries, improving the livelihoods of rural farm households via agricultural productivity would remain a mere wish if the agricultural technology adoption rate is low. Hence, there is a need to adopt the best agricultural technologies to increase production and productivity as well as the living standards of the rural community. The best way for developing countries to catch developed countries is through agricultural technology diffusion and adoption [6].

Adoption is defined by different authors differently. "Adoption commonly refers to the decision to use a new technology or practice by economic units regularly" [7]. According to Bonabana-Wabbi, [8] adoption is an outcome of a decision to accept a given innovation. Rogers (1983) defined 'adoption' as the use or not- use of new technology by a farmer at a given time. The adoption of improved agricultural technologies continues to be seen as an important route out of poverty in most of the developing world.

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Yet, agricultural innovations are often adopted slowly and several aspects of adoption remain poorly understood. These are considered as potential explanations for the low adoption of improved agricultural technologies. Agriculture is the supplier of basic human needs (Abera, 2009).

Different studies have been conducted on the adoption of agricultural technologies in Ethiopia [9]. However, many of them focus on a single commodity or technology and do not consider the possible inter-relationships between the various practices and intensity of adoption of a package of technologies.

There are different approaches to adopting new emerging technologies. These are:

- ✓ The bottom-up planning process involves farmers, extension agents, and researchers to identify the needs, priorities, and interests of target farmers (Koomen et al. 2015). The approach emerged based on the premise that all sectors of the economy have a role to play in the fulfillment of overall national developmental goals. Along with the same thinking, the classical approach has failed to take into account the contribution of several sub-sectors of the economy. This type of planning gives emphasis and is sensitive to local needs and resources. There are three levels at which people can participate in their development. Lowest level: - this is where the target group has a say only at the implementation stage of the project when they are allowed to “collaborate” with a development body that has already decided upon the designed project. This is not real participation- taken participation. Middle level: - this is where the target group is not involved in the identification stage of the project but has a say in the design stage and the implementation. Highest level: this is where the target groups have involvement and authority at all stages of project development.

- ✓ Classical (top-down) approach: is applied by the central agencies and works outwards from a starting concern with national conditions. It is usually the best approach to new endeavors. However, the approach concentrates power at the top over resources and decision-making; and is generally less sensitive than the bottom-up approach to local needs, resources and capacities. Therefore, the classical approach to project planning is becoming subject to more and more because of its rigidity and its less sensitivity to community participation.

- ✓ Participatory (holistic) approach: It is an encouraging trend that community-based development and sustainability, with its main component of environmental protection, are ideas that have started to gain acceptance in many circles. Community participation that is focused on community involvement in the planning, implementation, and evaluation stage of projects is an appropriate approach to sustainable development.

According to Tefera, Tesfay, Elias, Diro, & Koomen, [10] drivers of technology adoption broadly include factors that positively promote technology adoption. Drivers can be internal (based on the decision maker’s characteristics) or external (policy-related). Inhibitors are factors that de-motivate or discourage technology adoption. Likewise, inhibitors can be either internal or/and external factors. The selection of the model and non-model farmers has not been done by CASCAPE, but by the extension system. For this study [10] have adopted the official classification that the regional bureaus of agriculture (BoA) and the woreda offices of agriculture have put in place.

As part of developing countries in general and Sub-Saharan Africa in particular, Ethiopia is an agrarian country that predominantly relied on subsistence agriculture. According to the Ministry of Finance and Economic Development [11], since the 1990s as a national strategy, Ethiopia has espoused Agricultural Development-Led Industrialization (ADLI) which predominantly advocates smallholder agriculture and their transformation into commercial agriculture by employing agricultural technologies. Supporting this, the Ministry of Agriculture and Rural Development [12] inferred that majority of the country’s total production is been produced by smallholder farmers; and the sector contributes 90% of the foreign earnings and 70% of the raw materials for industry.

Smallholder farmers’ knowledge and use of agricultural technologies in general and improved maize varieties, in particular, are restricted due to various factors that are either internal or external to the farmers’ circumstances. The most commonly studied internal factors that affect the adoption and use of agricultural technologies are farmers’ attitudes towards risk [13]. Household characteristics that affect the level of production and consumption, resource endowments, etc. External factors could be access to technologies, in particular through a well-developed seed system [14,15,16,17,18], infrastructure, institutions markets, and enabling policy environments.

2. LITERATURE REVIEW

Adoption is an outcome of a decision to accept a given innovation [8]. Rogers (1983) defined 'adoption' as the use or not- use of new technology by a farmer at a given time. According to Feder et al., [13] adoption may be defined as the integration of innovation into farmers' normal farming activities over an extended period. Adoption, however, is not a permanent behavior.

Adoption is a decision to make full use of technology as the best course of action available. However, the adoption of production technology is not a unit and instant act; it consists of several stages and involves a sequence of thoughts and decisions. According to Youngseek and Crowston, (2011) adoption is a process that consists of three stages namely pre-adoption, adoption, and post-adoption. At the pre-adoption stage, people may examine new technology and consider adopting it. At the adoption stage, they form an intention to adopt the technology, and they eventually purchase and use it. At the post-adoption stage, people can either continue or discontinue using the technology.

The Adoption Process is the change that takes place within individuals concerning an innovation from the moment that they first become aware of the innovation to the final decision to either use it or not. Also, as is emphasized by Ray (2001) adoption does not necessarily follow the suggested stages from awareness to adoption; trial may not always be practiced by farmers to adopt new technology, they may adopt the new technology bypassing the trial stage. The adoption pattern for a technological change in agriculture is a comprehensive process. A large number of personal, situational, and social characteristics of farmers are related to their adoption rate.

2.1 Adoption of Improved Agricultural Technology

Agricultural new technologies constitute the introduction and use of hybrids, greenhouse technology, genetically modified commodities, chemical fertilizers, insecticides, tractors, and the application of other scientific knowledge (Matunhu J .,2011).

Most other studies also mention that technology adoption has a direct role in improving rural household welfare through increasing agricultural productivity [18].

According to Tefera et al., [10] region-wise, crop technology packages adoption shows the highest intensity in Amhara, followed by SNNP, Oromia, and Tigray regions. The overwhelming number of farmers in all studied regions responded that seed unavailability was the first major inhibitor for use of improved seeds of cereal crops. The major reason cited by farmers for not adopting row planting technology included the labor-demanding nature of the practice. The major inhibitors of pesticide use identified by farmers included high cost and unavailability. In most study regions, farmers practiced hand weeding instead of herbicide.

Researchers have argued that numerous factors can affect the decision to adopt a technology or packages of technology (Yu et al., 2010). The factors related to the characteristics of producers include education level, experience with the activity, age, gender, level of wealth, farm size, plot characteristics, labor availability, resource endowment, risk aversion, etc. The factors related to the characteristics and performance of the technology and practices include food and cash generation functions of the product, the perception by individuals of the characteristics, complexity, and performance of the innovation, its availability and that of complementary inputs, the relative profitability of its adoption compared to substitute technologies, the period of recovery of investment, local adoption patterns of the technology, the susceptibility of the technology to environmental hazards, etc. The institutional factors include the availability of credit, the availability, and quality of information on the technologies, accessibility of markets for products and inputs factors, the land tenure system, and the availability of adequate infrastructure, extension support, etc. Enabling policies and programs, market linkages, access to institutional support, and credit were found to play a positive role in stimulating farmer investment in and adoption of sustainable technologies [19].

2.2 Crop Technology Adoption

2.2.1 Adoption of improved rice technologies

Cultivation of rice in Ethiopia is generally a recent phenomenon it was started first at Fogera and Gambella Plains in the early 1970s, which is preceded by its utilization as a food crop. It is believed that a Dutchman introduced rice first in 1973 from Gambella to the Fogera Plain in the Amhara Region [20]. Even though, rice was introduced and tested initially in different areas of Ethiopia such as Gambella, Pawe, Woreta at the beginning of the 1970s, due attention was not given before the mid-1990s [21].

It is an essential food crop and a major food grain for more than half of the world's population. It is, a cereal crop, has been gathered, consumed, and cultivated by many people worldwide for more than 10,000 years longer than any other crop [22]. In the world, the largest volume of rice production is concentrated in countries China, India, Indonesia, Vietnam, Thailand, Bangladesh, Burma, Philippines, Brazil, and Japan. The percentage share of the above top ten rice producing countries accounts for about 32.9,24.4, 11.0, 7.0, 6.0, 5.4, 5.3 2.9, and 1.8% of the world production respectively. Ethiopia is 73rd in the world ranking with almost 0.0% (FAO, 2013).

Rice in Ethiopia has big potential to contribute to food security and even to generate foreign currency from its export [23]. Since 2006, Ethiopian rice production trends show increases in both area and productivity. The introduction and expansion of rice production in suitable agro-ecologies could be an option to achieve food security and self-sufficiency. Even though rice is not a traditional staple food in Ethiopia, it is considered a high potential emergency and food security crop. The trend of rice production is increasing both in area coverage, participant farmers, and production. (MoARD, 2011).

FAO [24] reported that four rice ecosystems were identified in the country. These are; upland rice, which is grown on naturally drained soils and where the water table always remains below the roots and is entirely rainfed; Hydro orphic (rainfed lowland) rice, which is grown on soils where the roots are periodically saturated by fluctuating water table in addition to the rainfall; Irrigated lowland ecosystem, whereby crop water requirement is entirely satisfied from irrigation, and rainfall is not a limiting factor and Paddy rice (with or without irrigation) which is grown under water-logged or submerged condition.

2.2.2 Adoption of improved teff technologies

Teff is a preferred staple food and cash crop in much of the highlands of the country. Teff is grown by 6.63 million farming households and accounts for 24.3% of all cultivated land, more than any other single crop in the 2013/14 cropping season. Teff can be grown under a wide variety of agro-climatic conditions, including elevations, rainfall, temperature, and soil conditions. Its optimal growing conditions coincide with its traditional production areas: 1,800–2,100 meters above sea level (masl), average annual rainfall of 750–1,000 mm, the average annual temperature of 10–27°C, and under a range of soil types [25]. Teff straw is a preferred feed for cattle [10].

To date, national-level teff varietal adoption estimates are unavailable in Ethiopia. A recent adoption study based on a sample of 450 randomly selected farmers in three major tef growing districts of East Shewa Zone (Ada, Lume-Ejere, and Minajar-Shenkora); however, suggest Quncho and DZ-01-196 (Magna) as the most important improved tef varieties grown by 76% and 40% of the sample farmers, respectively (Setotaw, 2013). The study further indicated that while adoption of Quncho increased from 5% in 2009 to 76% in 2012, the proportion of households using DZ-01-196 (Magna) declined from 84% in 2009 to 40% in 2012 signifying the increased importance of the latter in the study area. In terms of intensity of adoption measured by the area share of improved varieties from a total area under tef, Quncho stands first covering 66% followed by DZ-01-196 (Magna) accounting for about 26% of the total tef acreage. Over the two time periods, the area share of Quncho increased from 4% in the 2009 cropping season to 66% in the 2012 cropping season. On the contrary, that of DZ-01-196 (Magna) has dropped from 71% to 26% in the respective cropping seasons. The survey result showed that high yield, marketability, seed color, lodging tolerance, good germination, panicle length, and earliness were reported to be the most preferred traits of tef varieties.

2.2.3 Adoption of improved wheat technologies

Account for a similar share of national cereal production as sorghum with 17% of planted area and 19% of production. Bread wheat is the most widely grown variety throughout the highlands and mid-altitude areas. Wheat production typically takes place at altitudes of 1,600–3,200 masl in areas with an average annual rainfall of 400–1,200 mm and average annual temperatures of 15–25°C [10].

A study by Chilot, Moti, Bekele, Groote Hd, & Ali, [26] defining adoption as the use of improved wheat seeds recycled at most for not more than 5 seasons, estimated 63% of the sample households found to have adopted improved wheat varieties on 52.8% of the wheat area across the country. The same study indicated that seed recycling is common across the study areas mainly due to the absence of formal mechanisms for supplying new improved varieties and farmers' lack of awareness of recently released improved varieties. Hence, appropriate mechanisms need to be devised to bridge the gap between new variety release and seed multiplication, on one hand, farmer awareness, and adoption on the other hand. The results also show that farmers believe yields of improved wheat varieties increase dramatically when properly fertilized. As many as 76% of sample farmers used inorganic fertilizer (DAP) at an average rate of 68 kg/ha, indicating the need to find ways to improve fertilizer use. Similarly, adoption estimates of improved wheat varieties based on the 2013 study of tracking wheat varietal adoption using DNA fingerprinting revealed a high divergence between farmer responses-based estimates and DNA fingerprinting estimates (Yirga & Alemu). While farmer responses indicated that about 63% of the farmers used improved wheat varieties, the DNA fingerprinting suggested that about 96% of the respondents cultivated improved wheat varieties revealing the household survey underestimated the economic importance of improved varieties in the wheat sector by about 33 percentage points. The result based on farmer responses, however, is comparable with previous varietal adoption studies conducted in Ethiopia. Furthermore, the DNA fingerprinting identified some 23 improved wheat varieties are cultivated by smallholder farmers in the pilot areas revealing the household survey underestimated not only the level of use but also the diversity of the wheat varieties currently under cultivation.

2.2.4 Adoption of improved malt barley technologies

Malt barley is a recently introduced industrial crop for the production of malt to beverage industries and produced in various areas of the country. Barley is the fifth cereal crop in terms of area coverage grown in various areas of Ethiopia next to teff, maize, sorghum, and wheat. It is produced by more than 4 million households and covers more than one million hectares of farmland (CSA, 2014). Malt barley is among the multitude of crops that have received government attention. Hence, Ethiopia had no malt barley landraces, the introduction of improved malt barley technologies to smallholder farmers received due attention in high altitude areas of Ethiopia. It is grown as a cash crop in many developing countries and malt is the second largest use of barley. The popular uses of malt are the production of alcoholic beverages, bakery, and baby food industry. The Ethiopian malt barley market is fast-growing at 15-20% per year, driven by the corresponding market growth for beer [27].

The demand for malt and malt barley is increasing due to the improvement of production capacities of the existing brewery factories and the Asela malt factory. Competition of quality standards on domestically produced and imported malt barley grain and malt is low and unable to offer. Brewers are importing 45% to 60% of their malt requirements [27]. Ethiopia has suitable agroecology to produce malt barley and sustain the domestic demand. It is the second most important barley producing country in the African continent next to Algeria. The top barley producers countries in Africa for the year 2009 are Algeria and Ethiopia, with a production of 2.2 million and 1.5 million tons, respectively [24].

Many studies in Ethiopia indicate that barley has been used for various purposes such as increasing breast milk, remedy for gastritis, and healing of the broken bones and fractures [28]. The straw of the crop is used for feed, thatching roofs and bedding, bio-fuel, and prevention of algae growth in ponds and waterways [29]. It can be prepared for soup, stew, bread, and biscuit. The flour also has been used for supplementary feed to honey bee colonies [30].

2.2.5 Adoption of improved finger millet technologies

Finger millet (*Eleusine coracana* (L.) Gaertn) subspecies *coracana* belongs to the family Poeceae [31]. Millets are the most important cereals of the semi-arid zones of the world. For millions of people in Africa and Asia, they are stapled crops. Among millet crops, finger millet figures prominently; it ranks fourth in importance after sorghum, pearl millet, and foxtail millet [32]. The global annual planting area of finger millet is estimated at around 4-4.5 million hectares, with a total production of 5 million tons of grains, of which India alone produces about 2.2 million tons and Africa about 2 million tons. The important finger millet growing countries in eastern and southern Africa have been especially the sub-humid regions of Ethiopia, Kenya, Malawi, Tanzania, Uganda, Zaire, Zambia, and Zimbabwe. The archaeological findings of finger millet from Ethiopia date to about the third millennium BC [33]. The crop is mainly grown in the northern, northwestern, and western parts of the country, especially during the main rainy season. The national annual production area of finger millet in 2016/17 cropping season is estimated at around 456,171.54hectares, with a total production of 10.3 million quintals [34].

Finger millet cultivation is more widespread in terms of its geographical adaptation compared to other millets. It can withstand varied conditions of heat, drought, humidity, and tropical weather [32]. Also, it has high nutritional value and excellent storage qualities. Its grain contains 9.2% protein, 1.29% fat, 76.32% carbohydrates, 2.24% minerals, 3.99% ash and 0.33% calcium. In Ethiopia, the grain is used for making native bread, *injera*, porridge, cake, soup, traditional breakfast called "*Chachabsa*" malt, local beer, and distilled spirit (*Areki*) alone or in a mixture with *teff*, maize, and barley [18]. Finger millet can be stored for a period up to ten years or more without deterioration and weevil damage. However, its productivity is very low mainly due to shortage of improved varieties, weeds, insect (termite), diseases (blast), rat damage, shortage of rainfall, worm attacks, improper application of inputs (fertilizers and seed), and traditional management practices [35].

2.2.6 Adoption of improved maize technologies

Is the most widely cultivated cereal after teff in terms of area but is produced by more farms than any other crops. It accounts for the largest share of production by volume at 25.8%. Maize is grown chiefly between elevations of l500 and 2200 masl and requires large amounts of rainfall. The suitable temperature for maize is in the range of 19- 300c. As to the soil type, clay loam is preferred for maize production. In addition to food grain, maize residues are also used as fodder, fencing materials, and cooking fuel [10].

A more recent study by Yirga & Alemu, [36] aimed at tracking maize varietal adoption comparing DNA fingerprinting techniques with household surveys revealed interesting results.

2.2.7 Adoption of improved sorghum technologies

Sorghum (*Sorghum bicolor)* is the third most important cereal grain after Teff and Maize in Ethiopia both in area coverage and productivity. Sorghum is a major staple crop in the semi-arid regions of Ethiopia, particularly in the Somali Regional State. Sorghum does not only provide grains for human consumption, but also stover which is used as forage for livestock, building materials for housing, and as fuel for cooking [37]. Even though sorghum has multiple uses, its production is constrained by traditional farming techniques, and poor complimentary services such as extension, credit, access to market, and infrastructure.

Sorghum in Ethiopia is grown in three major agro-ecologies. It is the major crop in the dry lowland environment which accounts for more than 60 percent of the cultivated land [38]. As it is grown in diverse environments, the productivity of sorghum is constrained by several biotic and abiotic factors. The major constraints in the dry lowlands are drought, Striga, low yield, and insects [39].

In Ethiopia, considerable achievements have been obtained in developing early maturing and drought-tolerant sorghum varieties and production management practices. Due to the establishment of the sorghum program, more than 50 sorghum varieties have been released and the number of farmers growing improved lowland varieties reached 28 percent. The low level of improved sorghum variety adoption is attributed to the low availability of farmer-preferred varieties in sorghum variety generation and dissemination endeavors [40].

2.3 Factors Affecting Adoption and Intensity of Agricultural New Technologies in Ethiopia

Technology adoption in developing countries reveals that the various factors that influence technology adoption can be grouped into the following three broad categories (1) factors related to the characteristics of producers i.e., the farmers; (2) factors related to the characteristics and relative performance of the technology and (3) program and institutional factors [41].

The factors related to the characteristics of producers include education level, experience with the activity, age, gender, level of wealth, farm size, plot characteristics, labor availability, resource endowment, risk aversion, access to extension and agricultural research, etc. The factors related to the characteristics and performance of the technology and practices include food and cash generation functions of the product, the perception by individuals of the characteristics, complexity, and performance of the innovation, its availability and that of complementary inputs, the relative profitability of its adoption compared to substitute technologies, the period of recovery of investment, local adoption patterns of the technology, the susceptibility of the technology to environmental hazard, etc. The institutional factors include the availability of credit, the availability, and quality of information on the technologies, accessibility of markets for products and inputs factors, the land tenure system, and the availability of adequate infrastructure, extension support, etc. Enabling policies and programs, market linkages, access to institutional support, and credit were found to play a positive role in stimulating farmer investment in the adoption of sustainable technologies [19].

2.3.1 Demographic factors

According to Tefera et al., [10] adoption intensity decreased when the age of the household head and the dependency ratio in the household increased. Which implied the need for sufficient labor and openness in learning about the technology as it is relatively better known among young farmers. Households with better access to irrigation showed a significantly higher rate of adoption, and the level of adoption was positively associated with distance to the nearest market and the household annual cash income. The irrigation and income factors reflected that the investment capacity of the household increased adoption.

2.3.2 Socio-economic factors

The education status of the household head is the most common and important variable that is found to explain farmers' agricultural technology adoption behavior. Various studies confirmed that it has a significant positive influence on the adoption of technologies. In other studies, [17] household head's level of education was found to enhance awareness and decision-making, which was likely to increase the probability of adoption of SWC practices. Educated household heads may have enhanced practical awareness and understanding of an erosion problem and apply measures to control it rather than considering erosion as a curse. He strongly agrees that education has a positive and significant relationship with the adoption of agricultural technology. This is due to education having the power to change the knowledge, skill, and attitude of farmers. It also enhances the analytical and problem-solving skills of farmers. In addition, Education enhances the locative ability of decision-makers by enabling them to think critically and use information sources efficiently. Farmers with more education should be aware of more sources of information, and more efficient in evaluating and interpreting information about new agricultural technologies than those with less education. That is why agree those farmers who have better education status have a higher probability to adopt agricultural new technology than those we do not have [42]. Many studies conducted in different parts of Ethiopia showed that farmland, livestock holding, and access to different productive assets have been affecting the food security status of rural households in Ethiopia. Availability and amount of family labor play a vital role in determining the adoption and intensity of use of agricultural technologies. The existence of active work force in rural households usually encourages them to show interest in trying some agricultural technologies. Off course, the influence of labor availability on adoption depends on the characteristics of the technology to be adopted. When the new technologies in relative to the older ones are more attractive and labor-intensive, farmers with more labor would tend to adopt those technologies. Some new technologies are relatively labor-saving and others are labor using. For example, when technology is labor-saving like tractors, harvesters, pesticides, and the like, its impact will be negative. For those labor-using technologies, like improved varieties of seeds and fertilizer labor availability plays a significant role in adoption. Plenty of adoption studies found out a positive impact of family labor on technology adoption [17]. The reviewer argues that higher family labors increase the probability to adopt agricultural new technologies. Most of the Ethiopian farmers have not used labor-saving technologies like tractors, harvesters in their production system. They depend on labor-using technologies and agricultural new technology requires human resources from sowing to the final harvesting of the crop.

The impact of Farm size on adoption and intensity of use of agricultural technologies, on the other hand, is not consistently similar in various adoption studies. Some of the studies showed a positive influence of the variable on adoption decisions. For instance, studied determinants of adoption and intensity of use of improved maize varieties in the Central Highlands of Ethiopia and found a significant positive effect. Similar results by other researchers such as [43] also found a reverse effect of land size on the joint adoption of inorganic and improved maize varieties. It is reported that there is a positive relationship between farm size with adoption. The reviewer supported the argument provided by those researchers' farm size has a positive relationship with the adoption of agricultural new technologies this is because most the Ethiopian farmers have grown different varieties of crops, in turn, requires a larger farm size. In addition, most the Ethiopian farmers are involved in mixed farming (crop and animal production). According to Diiro off-farm income is expected to provide farmers with liquid capital for purchasing productivity-enhancing inputs such as improved seed and fertilizers. In another study conducted by Ibrahim et al. annual income of the respondent had a significant positive relationship with the adoption of recommended technologies in Bangladesh i.e., the higher the annual income of the respondents, the more they adopted recommended technologies. The influence of annual gross income was robust in our analysis and statistically significant in the adoption of teff, maize, wheat, barley, and sorghum technology package [44].

Hence, the resource endowment of farmers and their income-generating capacity is expected to have a positive impact on the likelihood of adoption of these technologies and practices (Yu et al., 2010).

2.3.3 Institutional factors

Institutional factors deal with the extent or degree to which institutions impact technology adoption by smallholders. Institutions include all the services to agricultural development, such as finance, insurance, and information dissemination. They also include facilities and mechanisms that enhance farmers' access to productive inputs and product markets. Extension service is a very crucial institutional factor that differentiates adoption status among farmers. In the existing situation, much of agricultural technology delivery is undertaken by the extension system. Access to participate in training, demonstration, field day, and other extensions services, therefore, create the platform for the acquisition of the relevant information that promotes technology adoption. Several studies have used different variables to measure farmers' access to extension services. A study conducted in four regions of Ethiopia shows that farmers who had more frequent contact with extension agents were more likely to adopt wheat technology as compared to farmers who had low frequent contact [45].

Organization membership is another factor influencing technology adoption. Studies by Abebaw & Haile, [46] and by Bati, [47] also demonstrated to the positive role of cooperative membership on technology adoption by smallholder farmers in Ethiopia. Katungi & Akankwasa, [48] found that farmers who participated more in community-based organizations were likely to engage in social learning about the technology, hence raising their likelihood to adopt the technologies.

Market distance of the respondents is important for the producers to get attractive market price through reduction of transportation cost. The increase in market distance make farmers to get out-dates market information and becoming out of adopting agricultural new technologies. The findings [45] showed that maize and teff technology package adoption improved as the households' residences became closer to market while the reverse held true for wheat technology package adoption. The market pulled technology adoption, and these findings agreed with results of Bayissa, [49]. The negative relationship between distance of the residence from an all-weather road and fertilizer adoption was reported by other studies. For instance, [50] found that distance to market centers was negatively and significantly related to adoption of fertilizer.

Decreasing the distance from the market decreased the transportation cost of agricultural inputs. Hence market distance and use of inorganic fertilizer had a negative relationship [43]. Access to credit service is the source of finance for the medium andlower-income households to buy inputs for agricultural production. In Ethiopia, the credit service is given in-kind and cash form especially credit services delivered for an agricultural production system. Different Authors conformed that farmers who have access to credit services had more probability to adopt the agricultural new technologies than otherwise. Daniel and Kafle confirm access to credit can increase the probability of adoption of agricultural new technologies by offsetting the financial shortfall of the households [51]. A similar finding indicates financial resources were necessary to finance the uptake of new technologies [43]. They indicated that households who had more access to formal and/or informal sources of credit significantly adopted the technology.

2.4 Impact of Improved Agricultural Technologies on Smallholder Farmers (Farm Income)

To identify the impact of the technology adoption on the sample households, in the study, outcome variables which are farm income & consumption expenditures of the farm households surveyed were analyzed using the propensity Score match of the adopters and non-adopters of the technology. Propensity score matching has the advantage of reducing the dimensionality of matching to a single dimension. This is the best possible procedure to follow since the households in both adopters and non-adopters‟ samples might have similar or closer propensity scores even though they might be dissimilar based on each covariate [52]. Based on the fact above, once the matching process is taken place, a comparable sample of control (non-adopters) is created which is similar to the adopters except for the decision of adopting the technology. So the outcome variables average income and average consumption expenditures of these two new samples of adopters and non-adopters were compared using the nearest neighborhood matching method of ATT estimation without any significant biases. The procedure of calculating ATT based on propensity score match method is consistent with the [2] who conducted a study on the potential impact of agricultural technology adoption on poverty alleviation strategies and found a positive effect of agricultural technology adoption on farm household wellbeing suggesting that there is a large scope for enhancing the role of agricultural technology in contributing to poverty alleviation. According to Mendola, [2], the propensity score matching(PSM) procedure balances distributions of observed covariate between adopters of technology and non-adopters based on similarity of their predicted probabilities of adopting the technology (matching their propensity scores).

2.4.1 Potential for economic and social impact

Agricultural productivity in Ethiopia chronically suffers from limited integration into national and regional market value chains and has low investments/benefits from research and development [53]. Understanding the specific agricultural development options and focusing on their implications for growth and poverty reduction, requires a framework that links potentially rewarding strategic directions to opportunities and constraints in agriculture in the region. The potential for sorghum and finger millet to catalyze regional development is high. Trade statistics from FAO show that in total, Africa imports up to 1 million tons of sorghum per year. Moreover, yield gains of sorghum and millets, if coupled with other enterprises, can stimulate up to 6% of Agricultural Gross Domestic Product (AgGDP) needed to stop extreme hunger and poverty [54]. Also, these crops have the potential to stimulate growth and resilience to the effects of climate change, thereby contributing to the achievement of the Millennium Development Goals (MDGs) which include: eradicating extreme poverty and hunger (MDG1), ensuring environmental sustainability (MDG7), promoting gender equality and empowering women (MDG3), and developing a global partnership for development (MDG8). Generally, this 8 project has potential to stimulate economic growth and sustainable development in the region as the livelihoods of more than 100 million people stand to be improved through more and better food and cash incomes.

3. CONCLUSION

Adoption of agricultural technology is a critical strategy for improving agricultural productivity, achieving food self-sufficiency, and alleviating poverty and food insecurity among Ethiopia's smallholder farmers. In Ethiopia, farmers have been adopting and using different agricultural technologies, the adoption rate of the technologies has not been at a good level when compared with other countries. The variables significantly affect the adoption of agricultural new technologies by farmers are age, availability of training, education level, family size, farm size, accesses to extension service and agricultural research, saving institution factor, providing participation of demonstration and credit access.

4. RECOMMENDATIONS

To solve problems of inadequate use of production technologies, decision-makers have pursued a range of policies and strategies to boost agricultural production and productivity.

To increase and instigate the likelihood of adopting modern agricultural technologies by smallholder farmers, policy makers should emphasize overcoming credit market failures, irrigation problems by introducing drip and pipe irrigations, securing land ownership status of farm households, and empowering female-headed households to be participants and agents of change by considering a comprehensive and integrated development of the country where their involvement is pertinent in all endeavors of the country’s overall development.

To solve problems encounter for the adoption of technology the decision-makers (Researchers) and policy makers (Government, MoA, Regional Agricultural office, and NGO) should form inter-relationships between the various practices and intensity of adoption of a package of technologies rather than a single commodity or technology.

To encourage the participation of farmers in new technology the policy maker should provide excess credit service, training, and invite them to participate in field demonstrations.

The Government, MoA, Regional Agricultural office, Zonal and woreda’s Agricultural office, NGO, Researchers, and scholars are needed to further promote agricultural new technologies by designing based on farmer’s problems and needs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Doss, Cheryl R, Morris, Michael L. How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural Economics. 2000;25(1):27-39.
2. Mendola Mariapia. Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh. Food Policy. 2007;32(3):372-393.
3. Becerril Javier, Abdulai Awudu. The impact of improved maize varieties on poverty in Mexico: A propensity score-matching approach. World Development. 2010;38(7):1024-1035.
4. Ajayi Olu C, Franzel, Steven, Kuntashula, Elias, Kwesiga, Fred. Adoption of improved fallow technology for soil fertility management in Zambia: Empirical studies and emerging issues. Agroforestry Systems. 2003;59(3):317-326.
5. Gemeda Abdissa. Farmers' maize seed systems in Western Oromia, Ethiopia: CIMMYT; 2001.
6. Foster Andrew, Rosenzweig Mark R. Barriers to farm profitability in India: mechanization, scale and credit markets. Paper presented at the Conference Agriculture for Development-Revisited, University of California at Berkeley; 2010. October.

7. Foster Andrew, Rosenzweig Mark. Inequality and the sustainability of agricultural productivity growth: Groundwater and the Green Revolution in rural India. Paper presented at the Prepared for the India Policy Conference at Stanford University; 2008.
8. Bonabana-Wabbi, Jackline. Assessing factors affecting adoption of agricultural technologies: The case of Integrated Pest Management (IPM) in Kumi District, Eastern Uganda. Virginia Tech; 2002.
9. Hailu, Berihun Kassa, Abrha, Bihon Kassa, Weldegiorgis, Kibrom Aregawi. Adoption and impact of agricultural technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia. International Journal of Food and Agricultural Economics (IJFAEC). 2014;2(1128-2016-92058):91-106.
10. Tefera, Tewodros, Tesfay, Girmay, Elias, Eyasu, Diro, MULUGETA, Koomen, Irene. Drivers for adoption of agricultural technologies and practices in Ethiopia. A study report from. 2016;30.
11. MoFED. Ethiopian. Rural development policy and strategies. Ethiopia: Ministry of Finance and Economic Development (MoFED), Addis Ababa, Ethiopia; 2003.
12. MoARD. Ethiopia's Agricultural Sector Policy and Investment Framework 2010–2020: Ministry of Agriculture and Rural Development (MoARD), Federal Democratic … ; 2010.
13. Feder, Gershon, Just, Richard E, Zilberman, David. Adoption of agricultural innovations in developing countries: A survey. Economic Development and Cultural Change. 1985;33(2): 255-298.
14. Byerlee Derek, Heisey Paul W. Past and potential impacts of maize research in sub-Saharan Africa: A critical assessment. Food Policy. 1996;21(3):255-277.
15. Croppenstedt Andre, Demeke, Mulat, Meschi, Meloria M. Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. Review of Development Economics. 2003;7(1):58-70.
16. Deressa, Temesgen Tadesse, Hassan, Rashid M, Ringler, Claudia, Alemu, Tekie, Yesuf, Mahmud. Analysis of the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia [in Amharic]: International Food Policy Research Institute (IFPRI); 2008.
17. Asfaw, Solomon, Shiferaw, Bekele, Simtowe, Franklin, Lipper, Leslie. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. Food Policy. 2012;37(3):283-295.
18. Asfaw, Solomon, Shiferaw, Bekele, Simtowe, Franklin, Hagos, Messia. Agricultural technology adoption, seed access constraints and commercialization in Ethiopia. Journal of Development and Agricultural Economics. 2011;3(9):436-477.
19. Shiferaw, Bekele A, Okello, Julius, Reddy, Ratna V. Adoption and adaptation of natural resource management innovations in smallholder agriculture: reflections on key lessons and best practices. Environment, development and sustainability. 2009;11(3): 601-619.
20. Alemu, Dawit, Thompson, John, Assaye, Abebaw. Rice commercialisation, agrarian change and livelihood trajectories: Transformations on the Fogera Plain of Ethiopia; 2021.
21. Wolelaw S. Factors determining supply of rice: A Study in Fogera District of Ethiopia. An MSc (Doctoral dissertation, Thesis presented to the School of Graduate Studies of Alemaya University 90); 2005.
22. Belayneh, Tamirat, Tekle, Jember. Review on adoption, trend, potential, and constraints of rice production to livelihood in Ethiopia. International Journal of Research-Granthaalayah. 2017;5(6):644-658.
23. Halos-Kim, Leonides. Value-addition, agro-enterprises, partnerships & market access. African Journal of Food, Agriculture, Nutrition and Development. 2015;15(5).
24. FAO, WHO. Principles and methods for the risk assessment of chemicals in food. Environmental Health Criteria. 2009;240.
25. Chamberlin Jordan, Schmidt, Emily. Ethiopian agriculture: A dynamic geographic perspective. Development Strategy and Governance Division, International Food Policy Research Institute–Ethiopia Strategy Support Program II: ESSP II Working Paper; 2011.
26. Chilot Y, Moti J, Bekele S, Groote Hd, Takele M, Ali O. Analysis of adoption and diffusion of improved wheat technologies in Ethiopia: Research Report 101. Ethiopian Institute of Agricultural Research (EIAR) and ….; 2013.
27. Tadesse Ayelech. Market chain analysis of fruits for Gomma woreda, Jimma zone, Oromia National Regional State. Haramaya University; 2011.
28. Kebede, Mekuria Wuletaw, Tadesse, Daniel. Determinants affecting adoption of malt-barley technology: Evidence from North Gondar Ethiopia; 2015.

29. Laage Damien, Stirnemann, Guillaume, Sterpone, Fabio, Rey, Rossend, Hynes, James T. Reorientation and allied dynamics in water and aqueous solutions. Annual Review of Physical Chemistry. 2011;62:395-416.
30. Riedel Simon, Clemens W, Workneh A, Temesgen A. Participatory assessment of incidence and perception of bovine trypanosomosis by cattle farmers in Dano, Western Ethiopia. Paper presented at the Conference on International Agricultural Research for Development 2007; 2007.
31. Adoukonou-Sagbadja H, Wagner C, Dansi A, Ahlemeyer J, Daïnou O, Akpagana K, Friedt W. Genetic diversity and population differentiation of traditional fonio millet (*Digitaria* spp.) landraces from different agro-ecological zones of West Africa. Theoretical and Applied Genetics. 2007;115(7):917-931.
32. Zewdu Asfaw, Gemechu, Fekede, Babu, Mideksa. Pre-Scaling up of Improved Finger Millet Technologies: The Case of Daro Lebu and Habro Districts of West Hararghe Zone, Oromia National Regional State, Ethiopia. Int. J. Agri. Educ. Exten. 2018;4(2):131-139.
33. Hilu KW, De Wet, JMJ, Harlan Jack R. Archaeobotanical studies of Eleusine coracana ssp. coracana (finger millet). American Journal of Botany. 1979;66(3):330-333.
34. Mwongera, Caroline, Shikuku, Kelvin M, Twyman, Jennifer, Läderach, Peter, Ampaire, Edidah, Van Asten, Piet, Winowiecki, Leigh A. Climate smart agriculture rapid appraisal (CSA-RA): A tool for prioritizing context-specific climate smart agriculture technologies. Agricultural Systems. 2017;151:192-203.
35. Gizaw, Wasihun, Assegid, Desu. Trend of cereal crops production area and productivity, in Ethiopia. Journal of Cereals and Oilseeds. 2021;12(1):9-17.
36. Yirga Chilot, Alemu Dawit. Adoption of crop technologies among Smallholder Farmers in Ethiopia: Implications for Research and Development. Eth. J. Agric. Sci. EIAR 50th Year Jubilee Anniversary. 2016;Special(1-16).
37. Abdelgani Migdam E, Hassan, Ilham A. The use of biofertilizers for increasing food production in Africa; 2006.
38. Cochrane Logan, Bekele Yeshtila W. Average crop yield (2001–2017) in Ethiopia: Trends at national, regional and zonal levels. Data in brief. 2018;16:1025.
39. Hoddinott John, Berhane, Guush, Gilligan, Daniel O, Kumar, Neha, Seyoum Taffesse, Alemayehu. The impact of Ethiopia's Productive Safety Net Programme and related transfers on agricultural productivity. Journal of African Economies. 2012;21(5):761-786.
40. Beshir Bedru, Sime, Mekonnen. Understanding farmers’ improved sorghum variety selection criteria: The case of farmer research group approach in Habro district: West Hararghe. Research Report 102; 2013. Available:http://www. eiar. gov. et.
41. Teklewold, Hailemariam, Kassie, Menale, Shiferaw, Bekele. Adoption of multiple sustainable agricultural practices in rural Ethiopia. Journal of Agricultural Economics. 2013;64(3):597-623.
42. Shiferaw, Bekele, Kassie, Menale, Jaleta, Moti, Yirga, Chilot. Adoption of improved wheat varieties and impacts on household food security in Ethiopia. Food Policy. 2014;44:272-284.
43. Ogada Maurice J, Mwabu, Germano, Muchai, Diana. Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. Agricultural and Food Economics. 2014;2(1):1-18.
44. Diiro Gracious M. Impact of off-farm income on agricultural technology adoption intensity and productivity. International Food Policy Reasearch Institute; 2013.
45. Tiruneh, Addis, Tesfaye, Teklu, Mwangi, Wilfred, Verkuijl, Hugo. Gender differentials in agricultural production and decision-making among smallholders in Ada, Lume, and Gimbichu Woredas of the Central Highlands of Ethiopia: Cimmyt; 2001.
46. Abebaw, Degnet, Haile, Mekbib G. The impact of cooperatives on agricultural technology adoption: Empirical evidence from Ethiopia. Food Policy. 2013;38:82-91.
47. Bati Mustefa. Determinants of Success and Coping Strategies of Collective Action in Ethiopia:-The Case of Agricultural Cooperatives; 2020.
48. Katungi E, Akankwasa K. Community-based organizations and their effect on the adoption of agricultural technologies in Uganda: a study of banana (*Musa* spp.) pest management technology. AGRIS, Food and Agriculture Organization of the United Nation; 2010.
49. Bayissa, Gedefa Weyessa. A double-hurdle approach to modeling of improved tef technologies adoption and intensity use in case of Diga District of East Wollega zone. Global Journal of Environmental Research. 2014;8(3): 41-49.
50. Gebresilassie, Leake, Bekele, Adam. Factors determining allocation of land for improved wheat variety by smallholder farmers of

northern Ethiopia. Journal of Development and Agricultural Economics. 2015;7(3):105-112.

51. Kafle Binod. Factors affecting adoption of organic vegetable farming in Chitwan District, Nepal. World Journal of Agricultural Sciences. 2011;7(5):604-606.

52. Rosenbaum Paul R, Rubin, Donald B. The central role of the propensity score in observational studies for causal effects. Biometrika. 1983;70(1):41-55.

53. Padulosi S, Mal, Bhag, Ravi, Bala S, Gowda J, Gowda KTK, Shanthakumar G, Dutta M. Food security and climate change: Role of plant genetic resources of minor millets. Indian Journal of Plant Genetic Resources. 2009; 22(1):1-16.

54. Dorward Andrew R, Kirsten Johann F, Omamo S. Were, Poulton Colin, Vink Nick. Institutions and the agricultural development challenge in Africa. Institutional economics perspectives on African Agricultural Development. 2009;1:3-34.
