IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Role of Enhanced Crop Productivity in Agrobased Development of Ethiopia: Future Perspectives

Tewodros Biru
Department of Plant Science,
College of Agriculture and Natural Resource Science,
Mizan-Tepi University, Ethiopia

Abstract

The government concerns have shifted from earlier emphasis on raising foreign exchange earnings by cash crops and the establishment of large-scale commercial farms and neglected cereal production from subsistence farmers which accounted more than 80% of the cultivated area. During the 1974–1991, by large towards increasing productivity of smallholders to attain food self-sufficiency at national level through research-generated information and technologies, increasing the supply of industrial and export crops and ensuring the rehabilitation and conservation of natural resource base. However, population growth, environmental degradation, climate-related decline of yield, low level of farm input innovation, capital constraints are among the pressing constraints. The direction, the rate of change and the level of steps the agriculture sector taking up on the ladder of transformation to commercialized agriculture from its initial subsistence. Of course, it should be noted that, except for the progress made during the last two and half decades, the agricultural sector in Ethiopia had remained stagnant for centuries with limited progress in few specific areas. Consequently, the outcome of the suggestion made in this paper is believed to serve as problem area indicators for concerned stakeholders to develop and implement corrective measures that could help to accelerate the speed of transforming the existing agriculture into profitable agriculture. Crops such as maize, teff, and wheat within the category of cereals have shown an increment that ranges from 1.65 qt/ha to 23.21 qt/ha for maize; from 0.48 qt/ha to 19.89 qt/ha for teff; and from 1.16 to 13.21 qt/ha for wheat over the last five years (2013/14-2017/18). Similarly, crops such as faba beans and linseed have shown an increment that ranges from 0.36 to 14.91 qt/ha for faba beans and from 3.60 to 25.67 qt/ha for linseed over 2013/14 and 2017/18 estimates following the same pattern, the results of the 2018/19. It is hoped and expected that these yield increments would rise further in future with the commitment and adoption of suggestions forwarded in this paper.

Key words: Agrobased development, crop productivity, fertilizer-use-efficiency, soil fertility, water-use-efficiency

Introduction

Ethiopian agriculture, characterized mainly by smallholder farmers is the dominant economic activity of the country. The growth and transformation plan (GTP II) by the Ethiopian government acknowledges that the agricultural sector is the country's most important engine for economic growth and poverty alleviation. This particular sector determines the growth of all other sectors and consequently the whole national economy. It constitutes over 50% of the gross domestic product (GDP), accounts for over 85% of the labour force and earns over 90% of the foreign exchange (MoA 2009). On average, crop production makes up 60% of the sector's outputs, whereas livestock accounts for 27% and other areas contribute 13% of the total agricultural value added. The sector is dominated by small-scale farmers who practice rain-fed mixed farming by employing traditional technology, adopting a low-input and low-output production system. The land tilled by the Ethiopian small-scale farmer accounts for 95% of the total area under agricultural use, and these farmers are responsible for more than 90% of the total agricultural output (Gebreselassie and Bekele 2010). The sound performance of agriculture warrants the availability of food crops. This accomplishment in agriculture does not only signify the adequate acquisition of food crops to attain food security, but also heralds a positive aspect of the economy. In regard to this, collective efforts are being geared to securing agricultural outputs of the desired level so that self reliance in food supply can be achieved and disaster caused food shortages be contained in the shortest possible time in Ethiopia. The prime role that agriculture plays in a country's political, economic and social stability makes measures of agricultural productions extremely sensitive.

Recognizing the immense growth potential of agriculture and its role in the transformation of the country's economy, the Government of Ethiopia set forth the Agricultural Development Led Industrialization (ADLI) strategy in 1993. The purpose of ADLI was to bring about a structural transformation in the productivity of smallholder farmers, in order to catalyze a robust industrial sector by maximizing the country's natural and human resources. The basis of the agricultural development strategy of the Government was therefore transforming the agriculture sector from subsistence, low input low output orientation into high input, high output, market orientated, production system. The total population of the country is estimated at 109 million (2018) of which 81 percent is rural. The annual population growth rate has been 2.6 percent over the period 2005-2015 and the average population density is 90 inhabitants/km² which varies from 7 inhabitants per km^2 in Afar in the northeast to 114 inhabitants per km^2 in Southern Region in the southwest of the country. The urban population is growing rapidly as a result of both population increase and high rural-urban migration. In 2014, the Human Development Index ranks Ethiopia 174^{th} among 188 countries and the Gender Inequality Index ranks it 129^{th} among 152 countries for which data are available. Life expectancy in Ethiopia was computed to be 64 years and the under-five mortality 62 per 1000 births in 2014, both progressing from 51 years at the end of the 1990s. looking at the resources available, it is however advisable to control growth of population in order to reduce the pressure on agriculture to gain efficient crop production per unit land per unit time and per capita.

Ethiopian agriculture has been suffering from various external and internal problems. It has been stagnant due to poor performance as a result of factors such as low resource utilization, low-tech farming techniques (e.g. wooden plough by oxen and sickles), over-reliance on fertilizers and underutilized techniques for soil and water conservation; inappropriate agrarian policy, inappropriate land tenure policy, ecological degradation of potential arable lands; and increases in the unemployment rate due to increases in the population. Agriculture progresses technologically as farmers adopt innovations. The extent to which farmers adopt available innovations and the speed by which they do so determine the impact of innovations in terms of productivity growth. Despite the fact that many areas of the economy have made progress, the livelihoods of small-scale farmers are still constrained by many impeding factors. Currently, only a small percentage of Ethiopian smallholder farmers is able to use mechanized tools on their lands. With an average of 80% of agricultural plots currently prepared by animals,

compared to 0.7 percent by machines, the productivity level can indeed still be improved by much. The forthcoming paragraphs shed light on various important production factors for enhancing crop productivity.

Major Food Crops, their Yield and Productivity

By and large, agriculture in Ethiopia is subsistence and the major food crops have been categorized into eight groups for simplicity of description and comparison purposes as the knowledge of these crops is imperative and prerequisite to the efforts for enhancing their productivity. The groups are cereals, pulses, oilseeds, vegetables, root crops, fruit crops, stimulant crops and sugar cane. Stimulant crops consist of Chat, coffee and hops. Crop yield per area is the most commonly used impact indicator for agricultural productivity activities. Crop yields are inevitably affected by many factors, these are weather, input price, changes in farming practices, amounts of fertilizer used, quality of seed varieties, and use of irrigation (CSA, 2019).

Grain Crops- This group refers to the major crop category that includes cereals, pulses and oilseeds, which not only constitute the major food crops for the majority of the country's population but also serve as a source of income at household level and a contributor for the country's foreign currency earnings, among others. The results of the year 2018/19 survey indicates that a total land area of about 12,727,191.21 hectares are covered by grain crops, i.e. cereals, pulses and oilseeds, from which a total volume of about 315,602,058.49 quintals of grains were obtained from private peasant holdings. Within the category of grain crops, cereals are the major food crops both in terms of the area they are planted and volume of production obtained. They are produced in larger volume compared with other crops because they are the principal staple crops grown in all the regions with varying quantity. The data obtained well underpin that out of the total grain crop area, 81.39% (10,358,890.13 hectares) was under cereals. Teff, maize, sorghum and wheat took up 24.17% (about 3,076,595.02 hectares), 18.60% (about 2,367,797.39 hectares), 14.38% (1,829,662.39 hectares) and 13.73% (1,747,939.31 hectares) of the grain crop area, respectively. Cereals contributed 87.97% (about 277,638,380.98 quintals) of the grain production. Maize, teff, wheat and sorghum made up 30.08% (94,927,708.34 quintals), 17.12% (54,034,790.51 quintals), 15.33% (48,380,740.91 quintals) and 15.92% (50,243,680.72 quintals) of the grain production, in the same order. Pulses are also among the various crops produced in all the regions of the country after cereals. Pulses are grown in different volumes across the country. Pulses grown in 2018/19 covered 12.73% (1,620,497.30 hectares) of the grain crop area and 9.54% (about 30,113,480.57 quintals) of the grain production was drawn from the same crops. Faba beans, haricot beans (white), haricot beans (red), and chick peas (white) were planted to 3.87% (about 492,271.60 hectares), 0.69% (about 88,302.71 hectares), 1.57% (about 200,334.52 hectares) and 1.28% (about 163,067.24 hectares) of the grain crop area. The production obtained from faba beans, haricot beans(white) haricot beans (red) and chick peas (white) was 3.30% (about 10,419,535.14 quintals), 0.48% (about 1,508,230.37 quintals), 1.07% (3,374,971.33 quintals) and 1.05% (3,301,531.98 quintals) of the grain production, in that order. Oilseeds refer to crops which are also classified within grain crops category, nonetheless. oilseeds are grown to flavour the food consumed at home and earn some cash for peasant holders in the country. Various oil crops are produced in all the regions with differing quantity added 5.88% (about 747,803.78 hectares) of the grain crop area and 2.49% (about 7,850,196.94 quintals) of the production to the national grain total. Neug, sesame and linseed covered 2.03% (about 257,950.40 hectares), 2.32% (about 294,819.49 hectares) and 0.66% (about 83,626.93 hectares) of the grain crop area and 0.94% (about 2,963,227.47 quintals), 0.64% (about 2,016,646.44 quintals) and 0.31% (about 966,855.92 quintals) of the grain production, respectively.

Vegetables – Peasant holders living near urban centers largely practice vegetable farming. Most vegetables are not commonly practiced by the rural private peasant holders, hence the small volume of production. Vegetables took up about 1.67% of the area under all crops at national level. However, of the total estimated area under vegetables, the lion shares which are about 71.37% and 20.09% were under red peppers and cabbage, respectively. Production of vegetables contributes 2.23% of the total crops production, conversely, of the total production of vegetables, the above mentioned crops have the lion shares, i.e. about 34.57% and 52.07%, in that order.

Root Crops - Some root crops like onion and garlic are indispensable to improve the taste and scent of the food we eat. Others like potatoes, sweet potatoes and taro are among the list of major food crops that are consumed across the country. These and other economic importance prompt the peasant holders to grow many of the root crops substantiates this point in more details. Enset is grown in southwestern part of the country and covers considerable land area within the private holdings. The number of Enset trees harvested in the 2018/19 agricultural year, from all over the country was estimated 136,088,791.00. Thus, the total produce in the form of Amicho, Kocho, and Bula is 34,470,255.16 quinals, 38,473,366.20 quintals and 1,164,694.12 quintals respectively.

Fruit Crops – The fruit crops grown by the private peasant holders cover only a small token area and production in the country. The number of holders practicing fruit farming is much less than that of grains or cereals. About 119,908.57 hectares of land is under fruit crops in Ethiopia. Bananas contributed about 55.11% of the fruit crop area followed by avocadoes that contributed 16.48% of the area. More than 8,343,562.20 quintals of fruits were produced in the country. Bananas, mangoes avocadoes, papayas, and oranges took up 60.11%, 16.02%, 10.16%, 7.10% and 4.94% of the fruit production, respectively.

Stimulant Crops– Farmers engaged in growing and producing stimulant crops such as coffee and chat are greater in number than those growing fruits. The area and production of these crops are also larger than that of fruits since they earn a considerable amount of cash for the holders. Chat and coffee shared 2.24% and 5.28% of the area under all crops in the country and 2,747,770.98 and 4,945,743.63 quintals of produce were obtained from these crops in the same agricultural year, respectively.

Sugarcane- It is grown in small areas in some parts of the country within the private peasant holdings. About 27,826.98 hectares of land were under sugarcane in the country, yielding an estimated total of 12,940,810.52 quintals of produce by the peasant holders. But the production is not usually used for industrial purposes. It is noticeably used up in household consumption.

Land Use and Soil Fertility Maintenance for Efficient Crop Production

The rapid growth of population has resulted in shortage of farmland, and fragmentation through time which, in turn, affect smallholder agriculture and sustainability of rural livelihoods. Thus, it calls for further interventions in family planning to limit the rapid population growth, intensification of agricultural production and enhancing non-farm activities (Teshome 2014). There is strong agreement about the current dire situation of Ethiopian agriculture. Population growth is outpacing agricultural production. Farmers grow crops by expanding farmlands for meeting short-term survival needs of increasing human population. Even in the highlands, people are encroaching to very steep slopes and marginal lands in order to expand cultivated land which is in its limit in these areas. Thus, farmers in Ethiopia are caught in a vicious circle of low level of income and low level of agricultural productivity though several attempts have been made to address environmental degradation, low agricultural productivity and food insecurity. This implies that population explosion and food insecurity are twin problems which must be addressed together for enhancing 'Agricultural Development Led Industrialization' of the nation's economy.

Given that the majority of the poor people in Ethiopia live in rural areas relying on agriculture, trends in land ownership, farm size, and fragmentation are of great interest. With a few notable exceptions, most environments have been consumed for rain-fed crop cultivation. The area suitable for rain-fed crop production is estimated to be about 18.74 x 10^6 km^2, only 3.75 to 4.00 x 10^6 km^2 above the area currently taken to represent this land cover. Land expansion will increasingly occur in environments assumed to be more marginal and fragile for cultivation and the intensification of cultivation through Green Revolution (GR) hybrid crops, synthetic inputs, and, more recently, biotechnology although the available data do not allow assessments of the spatial magnitude of these changes.

Trends of Cultivated Land

Cultivated land is a precious resource for Ethiopia's agriculture, particularly in the highlands. However, most of the country is covered by steep mountains, arid and semi-arid lands, or dry grasslands, which are unsuitable for agriculture. Although it is outpaced by population growth rate, the cultivated land has shown significant increment on temporal scales. The potentially cultivable land has already reached its limit in the highlands of Ethiopia. Second, most of the untapped land resources are concentrated in the lowlands which are drier than the highlands and suffer from inadequate amount of rainfall and low level of population density. There are no meaningful regional variations in ownership. Landownership is highest in Harari (97.9 percent) and Dire-Dawa (97.3 percent) followed by Amhara (97.1 percent and SNNP (96.9 percent) and lowest in Afar (90.9 percent). Across all rural areas, landownership declined by 1.6 percentage points between 1999/2000 and 2004/05. Farm size ranges from zero (landless) to a high of 5 hectares although those who own the latter are very small in number and usually reside in the less densely populated regions of Somali and Afar. The average landholding size for all the households is about 1.02 hectares per household.

The diminishing farm size has not only affected the profitability and level of technology use, but also the sustainability of rural livelihoods. Therefore, the interaction between population growth and environment can have one of the two general dimensions: human actions negatively affect the environment, and the environment negatively affects human activities. Although both dimensions are true, many of the increasing concern relates to the first dimension because food production potential of the environments has been largely damaged by high population pressure. Forecasting problems, perceiving consequences, and formulating appropriate policies will help to limit population growth and enhance agricultural production by preventing soil degradation and erosion and scientific management of salt-affected, acidity of soils, wetlands and nutrient deficiencies in particular and fast development of the country's economy in general.

Although about 66% of the country is suitable for agriculture, unprecedented population growth coupled with traditional practices has posed a tremendous impact on the land resources in the highlands where climatic conditions are more favorable for life and agricultural production. This high concentration of farming population in the highlands is resulting in land shortage, land fragmentation, total devoid of vegetative cover and erosion of the soil cover and exposure of extensive areas of the bedrock. On the contrary, larger proportions of the Ethiopian lowlands (55% of the total area of the country) are still sparsely populated (19% of the total population) due to a number of vector-born tropical diseases.

Production and Supply of Quality Seeds to Farmers

Accessibility to quality seeds is first and foremost component of package of practices aimed at enhancing crop productivity. When it comes to application of purchased modern seeds, the estimates are somewhat disappointing; with the exception of the Amhara region for the maize crops, basically the use of modern seeds is very limited in Ethiopia. However, as Spielman et al. (2011) pointed out that the numbers reported somewhat mask the actual use of improved seeds because they do not account for the use of saved seed from improved open-pollinated varieties

by the farmers. In an ideal farming condition, farmers should use fertilizer and improved seeds together to achieve optimal returns. However, our estimate of improved seed use is very low at 6.6 percent. The main reasons for this low estimate are (a) except open-pollinated variety seeds for wheat are often saved by farmers and not treated as a modern variety; (b) until recently there was no high yielding varieties of teff and (c) about improved seeds, farmers often buy them from the government agencies.

There are problems in the seed system as well (Alemu et al. 2010). The problem is particularly acute in the case of hybrid maize seed shortage which has become a national concern as farmers are unable to access seed in the quantities that they demand. This has resulted from constraints faced by both public- and private-sector operations, with the public sector accounting for 60 percent of hybrid maize seed production and the private sector accounting for the remaining 40 percent (Alemu et al. 2010). Markets for self-pollinated varieties also face problems. Farmers perceive insignificant advantage from seed in mass production over farmer-saved or locally-traded seed and hence, farmers have little incentive to purchase open-pollinated variety seed from the market. Furthermore, production of self-pollinated seed is a loss-making enterprise for the public system, so the private-sector companies have incentives to invest. These problems are well recognized by the government, and several initiatives are under way to address problems in the country's seed system. If they succeed, these programs will provide a further boost to fertilizer use in Ethiopia. Hence, production of quality seeds must be energized keeping this issue at the helm of the affairs. In addition, particular attention is to be paid by plant breeders to evolve a teff variety with strong and stiff stem so as to bear the load of panicle of greater yield potential without lodging.

Fertilizer Availability and Integrated Nutrient Management for Efficient Crop Production

Fertilizer use in Ethiopia has almost quintupled since the official elimination of input subsidy programs. Yet, application rates remain far below recommended level and, given limited scope for area expansion, fertilizer promotion continues to be the central focus for enhancing agricultural productivity. Unlike many other developing countries, Ethiopia has moved from partial liberalization in 1990s to government monopoly control over imports, with exclusive marketing through farmers' organizations, since 2008. In 2010, the government embarked on a new policy initiative, the Growth and Transformation Program (GTP), which sets annual production targets for cereals by regions. In line with the objectives of this program, government increased fertilizer imports from 440 thousand tons in 2008 to about 890 thousand tons in 2012. However, fertilizer availability (import plus change in stocks) far exceeded total consumption resulting in large carryover stocks reaching almost half a million tons—worth roughly US$350 million—sitting in the cooperative warehouses throughout the country in 2012. For further expansion of fertilizer use, two recommendations were made: (a) allowing private sector to participate in the domestic markets alongside cooperatives; and (b) paying more attention to other cereals— such as barley and sorghum— where fertilizer use is close to zero.

Agricultural productivity growth has been at the center of Ethiopia's development strategies since the country began the Agricultural Development Led Industrialization program in the early 1990s. The country has consistently allocated more than 10 percent of public spending on agriculture in the past 10 years (Fan et al. 2009; World Bank 2010) and has made concerted efforts toward agricultural intensification with special attention to the promotion of extension services and fertilizer use. Available data suggest that these policies have paid off in terms of both poverty reduction and overall growth performance (Dorosh and Rashid 2013). The growth in fertilizer use has been remarkable. In more than two decades following the introduction of fertilizer under the Freedom from Hunger program in the late 1960s, fertilizer use grew from 3,500 tons in the early 1970s to about 34,000 tons in 1985. In contrast, it grew from 140,000 tons in the early 1990s to about 650,000 tons in 2012. The growth in fertilizer use was triggered by the market liberalization programs in the 1990s. Since then fertilizer promotion has involved several policy changes, ranging from liberalization, with both public- and private-sector participation, to

government monopoly control over imports with exclusive marketing through farmers' cooperatives in 2008. After the input marketing parastatal, the Agricultural Input Supplies Enterprise (AISE), obtained monopoly control over imports, the government of Ethiopia adopted some ambitious policies to enhance agricultural productivity. The most visible policies include setting up specialized programs, such as the Agricultural Growth Program, Growth and Transformation Program, and the Agricultural Transformation Agency. The recent impetus for increasing fertilizer use has been largely driven by the Growth and Transformation Program, which sets annual cereal production targets for each region. Increasing the distribution of chemical fertilizer and improved seed has been the key move for achieving these targets. Only 30–40 percent of Ethiopian smallholders use fertilizer, and those who do apply on average only 37–40 kilogram per hectare (ha), significantly below recommended rates (Spielman et al. 2013). This rapid growth was promoted by providing subsidized credits to the cooperative unions to import and distribute fertilizer. However, the policy faced problems due to the rising cost of fertilizer and a balance of payment problems during 2007/2008. The government requested financial support from its development partners for and managed to receive $250 million from the World Bank and another fund worth 100,000 tons of fertilizer from the African Development Bank. Through some negotiations, the government and the two banks agreed to coordinate all fertilizer imports through AISE. This policy decision resulted in withdrawal of all holding companies except Wondo from fertilizer markets in Ethiopia.

Fertilizer Use Patterns

Although the Central Statistical Agency collects data on the use of organic fertilizer, I have considered only urea and diammonium phosphate (DAP) because they are the two main types of fertilizers used in Ethiopia. Three obvious trends are observed: first, there is an increasing trend in both planted area and fertilized area. While planted area has increased from about 7.0 million ha in 2003/04 to 9.7 million ha in 2010, representing a 38.6 percent growth. Second, more teff area appears to receive fertilizer than any other cereal crops, in all regions except SNNPR. At the national level, teff has consistently accounted for more than 40 percent of fertilized land. In 2010/11, of the total fertilized area of 2.31 million ha, 981,000 ha were allocated to teff, which is almost 75 percent more than maize or wheat. It may seem counterintuitive that farmers are using more fertilizer in a low-yielding crop like teff. However, this is consistent with the fact that teff prices have been increasing in real terms for many years. As a result, price has become more favorable relatively for teff than for other cereals. In addition, due to ease of storage and long shelflife, farmers attach some intrinsic values to teff.

Finally, fertilizer use in other cereals (for example, barley, sorghum, rice, and millet) is miniscule relative to the three major cereals and the land allocated to them. Since 2003/04, about 2.6 million ha, equivalent to 35 percent of total planted land, has been allocated to these cereals; but only about 4 percent of this land is fertilized. However, some concerted policy efforts have been made to change that in the coming years, especially for barley and rice. The Ethiopian government has been able to attract two large brewing companies from Europe, Heineken and Diageo, to set up their brewing plants in Ethiopia. Heineken will now have the largest brewing plant in Ethiopia and recently signed a Memorandum of Understanding with the government to develop the barley value chain (Tadele 2013). The Diageo, which acquired a local brewery (Meta Brewery) for $250 million, also has signed a Memorandum of Understanding and plans to procure barley locally through contract farming, which is now grown on about a million ha of land. On the other hand, the government of Japan is supporting promotion of rice in Ethiopia, under which the rice-growing area is expected to increase from 156,000 ha in 2009 to 463,000 ha by 2014 and 774,000 ha by 2019 (MoARD 2010). Under this strategy, irrigated land was expected to almost triple from 26,000 ha to 78,000 ha by 2014 and then increasing to grow to 775,000 ha by 2019 (Assefa et al. 2011). If these initiatives are successful, fertilizer use in Ethiopia will substantially increase in the coming years. In examining future potentials in fertilizer use and productivity enhancement, another way to look at fertilizer application is by combining it with modern input use. In the four major cereal production regions, about 37 percent of the cereal-

growing farmers apply fertilizer, with Amhara region leading the way at about 50 percent. About one-third of the cereal-growing farmers in Oromia and SNNPR use fertilizer, but only about 22 percent do so in Tigray.

Retail prices of two major types of fertilizers, DAP and urea, in Ethiopia are lower then in other neighboring countries. Another major element of the costs of fertilizer promotion in Ethiopia is the costs associated with the carry-over stocks. Regarding future potential, this paper highlights two areas of growth. The first area is increasing fertilizer use in other cereals. Currently, about 2.6 million ha, 35 percent of total cultivated land, are allocated to cereals (barley, rice, millet, and so forth), but only about 4 percent of this area is fertilized. Even less fertilizer is used in the high-potential regions of Amhara and Oromia, where 1.9 million ha of cultivated land is allocated to these crops. These crops have received little attention until recently. As mentioned earlier, the government has been able to attract two large brewing companies from Europe, Heineken and Diageo, to set up brewing plants in Ethiopia. This public–private partnership is likely to boost fertilizer use in barley. There are also initiatives to promote rice, for which irrigated land was expected to triple from 26,000 ha to 78,000 ha by 2014, and increase even more to 775,000 ha by 2019. The other initiative that is likely to increase fertilizer use is the establishment of blending facilities for mix of N, P, S, Zn, and B. If successful, this will not only lower costs and increase the returns to fertilizer use but also directly contribute toward soil fertility management.

Accelerated growth in agricultural productivity continues to be an important area of focus. More emphasis will be given to high-value crops and livestock production complemented by the establishment of a market system that benefits farmers and non-farm rural actors, maintaining environmental sustainability, promoting climate change adaptation and mitigation etc being an underlying principle. The Ethiopian government considered the Agriculture sector as critical sector so as to realize growth in the other sectors such as industrial and manufacturing. As a result, the government has consistently invested at least 10% of government spending to agriculture since 2003. This strong support has resulted in an average growth rate of over 7% per year in the sector, which has contributed a lot to the double digit annual growth rate of the overall economy. The agricultural sector in Ethiopia is currently composed of 12.6 million smallholder farmers (who operate on farms averaging 1.2 hectares each) and several hundred commercial farms. The combined annual crop production of these two groups of farms is 31 million tons, with 71% of this output comprised of grains (cereals, pulses, and oil crops); the remainder being vegetables, fruits, and cash crops (mainly coffee, sugarcane, chat, and enset). Growth in the sector has been near 8 percent in recent years and in value terms the combined output of the agricultural sector is now worth an estimated Birr 221 billion ($13 billion) according to the latest GDP statistics. However, there are many constraints that hamper agricultural productivity in Ethiopia. Among the key factors, soil fertility depletion is one. Ethiopian soils have been subjected to severe degradation caused by natural and man-made factors. The use of chemical fertilizer and improved seeds is quite limited despite Government efforts to encourage the adoption of modern, intensive agricultural practices. Smallholder farmers still use lower fertilizer application rates compared with their counterparts in east Africa. Urea and DAP are the only fertilizer sources that have been in use for the past four decades in Ethiopia. This is based on the fact that nitrogen and phosphorus, in that order, are the most limiting nutrients in its soils. Previous findings from FAO assisted fertilizer demonstration trials carried out in the country in the seventies through the Freedom from Hunger Campaign showed the importance of the two nutrients; at the time, results from these trials showed that response to other nutrients was not consistent or significant. Thus, until recently, use of other nutrients was not practiced. On the other hand, there are reports that indicate sharp increases in yield due to application of potassium, sulfur and zinc in different parts of the country. As a result, the country has started using fertilizers which can supply the deficient nutrients and will continue to use in the form of blends. Even though the amount of fertilizer imported increases every year, Ethiopian farmers still lag far behind other developing countries in fertilizer use. The average intensity of fertilizer use in the country (which is roughly less than 40 kilograms per hectare) remains much lower than elsewhere (e.g., 54 kg/ha in Latin America, 80 kg/ha in South Asia, and 87 kg/ha in Southeast Asia).

Going by the recommended dosages of N, and P for different crops teff, wheat, maize and barley are the main consumers of fertilizers.

The scenario fairly suggests that there was no much effort to improve the fertilizer use in the country that has a variable agro-ecology and soil conditions. The unbalanced use of fertilizer in the sense of soil fertility (which is assessed according to the gap between recommended dose and type of fertilizer and its actual use in fields) became evident in recent years. The significant gap between the recommended dose and actual amount of fertilizer given to land is very high in case of urea. Due to unbalanced use of fertilizer; the loss in soil fertility is also significant in Ethiopia. These aggregate trends mask great variability in fertilizer use trends across the different regions of Ethiopia. The above data shows that DAP is being gradually substituted by NPS in the past two years to meet the sulfur demand of most of Ethiopian soils. The future direction of the country is to locally produce tailored blends recommended based on soil fertility mapping and crop response information that are being generated through collaborative efforts among regional and federal research.

Fertilizer Use by Crop

The majority of the fertilizer is used for production of cereals, mainly applied to teff, maize, wheat, barley and sorghum in that order. Fertilizer use is concentrated on cereals followed by pulses and oil seeds, respectively. During 2014/15 cropping seasons the national level amount of both urea and DAP fertilizers applied in cereals, pulses and oil seeds were 769,940.9, 29,555.5 and11,371.1 tons, respectively (CSA 2014). Teff is the crop with the largest share in fertilizer use among the cereals (32 %), followed by maize and wheat with respective shares of 29% and 25% in the period 2010/11 and 2014/15. The application rate for fertilizers is increasing from year to year. For instance, in 2014/15, the application rate per hectare of cultivated land was 177 kg/ha for maize, 147 kg/ha for wheat and 110 kg/ha for teff. These statistics indicate that the national level intensity of fertilizer use is still lower than the blanket recommended rate of 200 kg per ha (100 kg of each urea and DAP for small cereals) and 200 kg urea and 100 kg DAP for maize, which in itself is also small. Besides this, farmers tend to use more DAP than urea when they apply them alone. This indicates that farmers are not applying both the right type and right amount of fertilizers. Further, to enhance the fertilizer-use-efficiency and crop productivity on the one hand and to reduce the load of pollution on the other, research must be initiated on nanofertilizers for different crops at the regional and national levels.

Water Resources and Judicious Use of Water for Enhanced Crop Production

Ethiopia is endowed with a substantial amount of water resources but very high hydrological variability. The surface water resource potential is impressive, but little developed. The country possesses twelve major river basins, which form four major drainage systems: All river basins except the Nile basin face water shortages (EU 2011). Most of the rivers in Ethiopia are seasonal and there are almost no perennial rivers below 1500 m altitude. About 70 percent of the total runoff takes place during the period June-September. Dry season flow originates from springs which provide base flows for small-scale irrigation.

Intense rainfall sometimes causes flooding particularly along the Awash river and in the lower Baro Akobo and Wabe-Shebelle river basins causing damage to standing crops and infrastructures. The construction of dykes mitigates the problem but has not provided a long-lasting solution. Ethiopia has 11 freshwater lakes and 9 saline lakes, 4 crater lakes as well as over 12 major wetland areas. The total area of wetlands in Ethiopia is estimated between 1.4 and 1.8 million ha (EPA 2003; IUCN 2010). Floodplains are mostly found in the northwestern and western highlands, the Rift Valley and the eastern highlands but some are also located in lowlands. The groundwater potential of the country is not known with any certainty, but so far only a small fraction of the groundwater has been developed. It is however more easily available than surface water in the arid areas and

supplies about 80 percent of the existing drinking water sources. Traditional wells are widely used by nomads. Internal renewable surface water resources are estimated at 120,000 million m³/year and renewable groundwater resources at around 20,000 million m³/year, but 18,000 million m³/year is considered to be overlap between surface water and groundwater, which gives a value of total internal renewable water resources of 122,000 million m³/year. External water resources are null and the surface water leaving the country is estimated at 96,500 million m³/year. Ethiopia has many small, medium and large reservoir dams constructed for hydropower generation, irrigation and drinking water supply. There are currently 12 hydropower plants cumulating a total installed capacity of 1945 MW (ODI 2015). Micro-dams, i.e. dams with a water storage capacity of less than 0.15 million m3, were constructed for small-scale irrigation, especially around 1999 and 2000 in the Amhara and Tigray regional states. Total dam capacity was estimated at 6,540 million m3 in 2008, and increased tremendously in recent years to reach about 31,484 million m3 in 2015. The new Tekeze dam, built on the eponym river in the Nile basin and completed in 2009, has a storage capacity of 9,000 million m3 and thus largely exceeds the previous largest Koka dam (1,900 million m3). The new Gilgel Gibe III dam, built on the Omo river, has a storage capacity of 14,000 million m3 and started to generate electricity after its completion in 2015. It will soon be supplemented by the Grand Ethiopian Renaissance Dam (GERD) started in 2011 on the Abbay (Blue Nile) river close to the Sudanese border mostly for hydropower generation. The GERD dam, expected to create a huge reservoir of 79,000 million m3, is almost 70 percent completed as of 2019.

Agriculture is by far the main water-withdrawing sector. Based on the total irrigated area, cropping pattern and calendar, annual agricultural water withdrawal was estimated to be in the order of 5,200 million m3 in 2002. Agricultural water withdrawal in 2016 was estimated at around 9,000 million m3. The huge livestock population withdraws an estimated 687 million m3 in 2010 (EU 2011). Evolution of irrigation development river basin master plan studies and related surveys indicate a maximum irrigation potential of about 5.7 million ha, but about 3.7 million ha is commonly quoted. The irrigation potential of Ethiopia is at present estimated at about 2.7 million ha, considering the availability of water and land resources, technology and finance. Modern small-scale irrigation through community schemes started only in the 1970s to fight major droughts and famines, especially the 1973 one. In 2004, the water managed area was estimated at 510,000 ha, of which 175 300 ha as estimated to be under full control irrigation. However, a research estimated that about 30 percent of the command area was not operating at that time (IWMI 2010). In 2015, the area equipped for full-control irrigation was estimated at 658,340 ha. The area equipped for community spate irrigation is estimated at around 200,000 ha, giving a total area equipped for irrigation of 858,340 ha. In addition, around 1100,000 ha was estimated to be cultivated by small farmers using temporary structures. Thus, in total around 1958,000 ha was considered to be water managed in 2014/15 (NPC 2015).

Irrigation schemes in Ethiopia are distinguished by irrigation technologies however, traditional ones often small-scale and community-based, carried out by farmers on their own initiative, including in peri-urban areas particularly in Addis Ababa and Bahir Dar are practiced for the production of vegetables for the local market. About 73 percent of the public irrigation schemes are located along the Awash river. Most of the water used for irrigation is surface water, while groundwater use was just started on pilot basis in East Amhara. Surface irrigation methods dominate throughout, predominantly furrow irrigation for cotton and wheat and basin irrigation for commercial fruits such as bananas. Sprinkler irrigation is being practiced on about 10,000 ha area likely to increase to 16,000 ha for sugarcane on Fincha State Farm. Similarly, it is being used in limited areas of eastern Amhara and southern Tigray in some smallholders' schemes and some private farms in the Rift Valley. Most of the earlier schemes were pump-irrigation projects, but later gravity irrigation schemes were introduced. Some private farms had installed hydraulic rams on the banks of the Awash river to lift up water (MoA 2011). Finally, rainwater harvesting, also sometimes named micro-irrigation in national documents, is well developed in the country, although estimates vary again

widely: from 40,000 to 800,000 ha, certainly encompassing the basin catchment for the latter figure. Role of irrigation in agricultural production, the economy and society cannot be overemphasized. Irrigated agriculture contributed less than 3 percent of the total cereal production in the early 2000s. By 2010, it contributed 9 percent of the agricultural GDP and 3.7 percent of the overall GDP. Over 1.2 million private holders practiced irrigated agriculture in 2014/15 in the Meher season–main rainy season–and over 0.8 million in the Belg season–small rainy season. Irrigated crops in medium and large scale commercial farms are mostly cash crops, in particular cotton and sugarcane, but fruits and vegetables were also introduced. Large-scale irrigation schemes are under full irrigation throughout the year. In small-scale irrigation schemes, irrigated crops are more diversified, but for the country as a whole the main irrigated crops are cereals–maize, wheat, barley or teff–, pulses, vegetables, root crops, fruits and fiber crops (cotton). Smallholder irrigators generally prefer subsistence crops rather than cash crops (MoA 2011) and use irrigation to complement rainfed agriculture, i.e. supplementary irrigation. However, during the dry season, they use full irrigation to get additional income.

The Ministry of Agriculture (MoA) is incharge of water management (irrigation extension), including water harvesting for smallholder irrigated and rainfed agriculture. The Ministry of Environment and Forestry (MoEF) is responsible for the preparation of environmental protection policy, laws and directives. The water management of small-scale irrigation schemes is the responsibility of the farmers themselves, mainly through informal/traditional community groups. Apart from the provision of extension and training services to the WUAs from the MoA, no institution is directly involved in water management in smallholder-irrigated agriculture. Once the construction of irrigation schemes is completed, they are handed over to the beneficiaries but maintenance remains within the responsibility of the regional governments. The absence of any appropriate local-level organs to cater for small-scale irrigation has resulted in a lack of guidance in irrigation operation and maintenance at a community level. With an increase in irrigated areas and more users, irrigation water management and rules for water allocation are becoming more complex and problematic. Water Resources Management Regulation 2005 (No 115) makes provision for maintaining environmental flows, protecting or restoring ecosystem services and addressing the water needs of marginalized groups but its enforcement is not rigorous (ODI 2015). River Basin Councils and Authorities Proclamation 2007 (No 534) authorizes RBHCs and RBAs for each major river basins. To develop the huge irrigated agriculture potential for the production of the food crops and raw materials are needed for agro-industries in a sustainable way. It emphasizes decentralization and user-based management of irrigation systems, development of priority schemes, support and enhancement of traditional irrigation schemes, establishment of water allocation, as well as integration of appropriate drainage facilities.

Recurring droughts and growing population pressure drove Ethiopian government to prioritize irrigated agriculture in the country's development agenda in order to reduce the food deficit. Ethiopia's first Growth and Transformation Plan (GTP) targeted again a colossal increase in irrigated land area for the period 2010- 2015, for a total of 1.85 million ha in small irrigation and an additional 785 583 ha in medium and large irrigation schemes by 2015. These were almost reached but mostly through traditional water management often with temporary structures not full-control irrigation schemes. The second GTP set a vast increase once more for the period 2015-2020, although this small scale irrigation target is lower than in the 2010-2015 GTP, with 1.7 million ha under small irrigation schemes and 954,000 ha under medium and large scale by 2019/2020 to develop 98 percent of the irrigation potential. Area under irrigation is mostly expanded with small irrigation schemes requiring lower capital and technical investments and reaching small communities. However, despite the immense increases mentioned above, the harvested irrigated crops were not yet using this new potential fully. In addition, the rapid infrastructure development should be quickly followed by institutional development and in particular creation of water use agents for local irrigation management to ensure that these new irrigation schemes are properly managed, operated and maintained. Further, for better water-use-efficiencies water productivity and enhanced crop productivity scientific irrigation scheduling

based on soil water potential and/or leaf water potential and crop stress index of crops must be adopted. Also, trickle irrigation should be encouraged for raising fruits and vegetables.

Mechanization for Improving Agricultural Productivity

Mechanization has enormous practical relevance to the Ethiopian agricultural sector and has already shown its ability to boost agricultural productivity. Smallholder farmers that have mechanized their means of production have also drastically increased their agricultural yields. Simple tools such as seed drilling machines, for instance, can double the yield of certain types of crops. A wide range of substantial education programs for agricultural businesses, geared towards providing technical training and stimulating the use of simple machinery, are already in place.18 Such trainings are provided by several foreign organizations active in Ethiopia, such as the German Agency for International Cooperation (GIZ). Consequently, a basis of knowledge for the use of machinery in the agricultural sector has already been laid down, providing fertile ground for the stimulation of further mechanization. A critical side to note this strength is that most of these developments have been limited to larger commercial farms, instead of smallholder farmers. The characteristics of the Ethiopian agricultural sector however, pose serious difficulties to switching to mechanical farming. Ethiopian smallholder farmers lack capital to invest in agricultural machinery. Moreover, the use of machinery on small and scattered agricultural plots is rarely cost-effective. Mechanizing Ethiopian smallholder farmers will only be beneficial if they also improve access to local markets or other parts of the value-chain through infrastructural investments. For instance, a tractor designed to carry heavy weights around a smallholder farm is not very useful when it is unable to reach the nearest market due to lacking basic infrastructure. Mechanization in isolation is therefore rarely sufficient by itself in improving smallholder farmers' productivity. Mechanization is often achieved with support from foreign donors, who provide funding and required training on how to operate these machines. The Ethiopian government has initiated, for example, a leasing program for tractors and other machinery and training for smallholder farmers on increasing agricultural yields. The Ethiopian Government particularly seeks to empower female and young farmers in rural areas to escape from poverty through the introduction of new farming techniques. Efforts to improve productivity of smallholder farmers could thus potentially benefit from the momentum provided by governmental investment commitments. This way, initiatives to employ mechanization to promote the agricultural sector in Ethiopia can address inequality issues as well.

Precision Agriculture, **Satellite Farming or Site-Specific Crop Management**

It is a farming management concept that is based on observing, measuring and responding to inter- and intra-field variability in crops. The goal of precision agriculture research is to define a decision support system (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources (McBratney et al. 2005). The practice of precision agriculture has been enabled by the advent of global positioning system (GPS) and Global Navigation Satellite System (GNSS). The farmer's and/or researcher's ability to locate their precise position in a field allows for the creation of maps of the spatial variability of as many variables as can be measured (e.g. crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, EC, Mg, K, and others). Similar data is collected by sensor arrays mounted on GPS-equipped combine harvesters. These arrays consist of real-time sensors that measure everything from chlorophyll levels to plant water status, along with multispectral imagery. This data is used in conjunction with satellite imagery by variable rate technology (VRT) including seeders, sprayers, etc. to optimally distribute resources. However, recent technological advances have enabled the use of real-time sensors directly in soil, which can wirelessly transmit data without the need of human presence.

Precision agriculture has also been enabled by unmanned aerial vehicles like the DJI Phantom which are relatively inexpensive and can be operated by novice pilots. These agricultural drones can be equipped with multispectral or red, green, and blue (RGB) cameras to capture many images of a field that can be stitched together using photogrammetric methods to create orthophotos. These composite maps contain multiple values per pixel in addition to the traditional red, green blue values such as near infrared and red-edge spectrum values used to process and analyze vegetative indexes such as Normalized Difference Vegetation Index (NDVI) maps. These drones are capable of capturing imagery and providing additional geographical references such as elevation, which allows software to perform map algebra functions to build precise topography maps. These topographic maps can be used to correlate crop health with topography, the results of which can be used to optimize crop inputs such as water, fertilizer or chemicals such as herbicides and growth regulators through variable rate applications for enhancing crop productivity maintaining sustainability of agriculture in the wake of global warming and changing climate.

Strengthening of Extension Services to Deliver Technology-Generated Package of Practices to Farmers

The package of practices such as INM, IPM, maintaining plant population, fertilizer application, irrigation scheduling etc. is to be adopted. Knowledge and awareness about the relative importance of package components to overall yield give farmers room for fexibility in stepwise adoption of the technology, according to their conditions and resources. Development agents, extension professionals, subject matter specialists, farmers' representatives, politicians and researchers tend to contact farmers. Policy makers and donor agencies have so far emphasized the use of modem farm technologies as a sole source of agricultural growth in Ethiopia. However, the cost of modern technologies is so prohibitive that few farmers in limited areas of the country have so far reached. Therefore, it is high time to explore possibilities for identifying approaches that could complement existing strategies of growth. When many African countries have shown limited commitment to supporting smallholder agriculture and when many neglected agricultural extension services in particular, the government of Ethiopia invested in both (Welteji 2018).

Education is Key to Agricultural Development

For the successful adoption of new technologies education is necessary. Around 80 percent of the children in 2010 were enrolled in primary education, thus almost doubling the 2000's rate with a reduced gap between boys (82 percent) and girls (78 percent) compared to that period (50 percent of boys against 39 percent of girls). Adult literacy was 39 percent for the 2005-2012 period (UNDP 2017) with a gap between female literacy (29 percent) and male literacy (49 percent). Poverty is still widely spread as it concerns almost a third of the population (30 percent) and is more concentrated in rural areas. Ethiopia's higher education ecosystem has not only grown and diversified rapidly over the past few decades, it is bound to expand exponentially in the years ahead, driven by factors like population growth, rising income levels, and climbing upper-secondary enrollments. In 2013 the British Council projected that the number of tertiary students in Ethiopia will increase by an additional 1.7 million by 2025. In the light of these trends, the federal government in 2015 greenlighted the construction of 11 new universities which have now been gone upto 44 operational public universities (up from 33). Education stands as the driving force for generating an adopting new agricultural technologies for enhanced crop productivity.

References

Alemu, D., Rashid, S. and Tripp, R. 2010. Seed system potential in Ethiopia: Constraints and opportunities for enhancing the seed sector. International Food Policy Research Institute. Washington DC.

Assefa, K., Alemu, D. and Shirator, K. 2011. Challenges and opportunities of rice in Ethiopian agricultural development. Addis Ababa: Ethiopian Institute of Agricultural Research. www.jica.go.jp/project/ethiopia/001/materials/ku57pq00000kj6meatt/seminar_02.pdf.

CSA. 2019. http://www.csa.gov.et/survey-report/category/355-eth-agss-2017?download=871:report-on-area-and-production-of-major-crops-2010-meher-season 2018-19

CSA. 2014. Various years. statistical abstracts and statistical bulletins. Addis Ababa: CSA, Federal Democratic Republic of Ethiopia.

Dorosh, P., and Rashid, S. 2013. Food and agricultural policy in Ethiopia: Progress and policy challenges. Philadelphia: University of Pennsylvania Press.

EPA. 2003. State of environment report of Ethiopia. Environmental Protection Authority. Addis Ababa.

EU. 2011. Managing water for inclusive and sustainable growth in Ethiopia: Key challenges and priorities. European report on development. European Union.

Fan, S., B. Babatunde, and Lambert, M. 2009. Public spending for agriculture in Africa: Trends and composition. Working Paper No. 28. Africa: Regional Strategic Analysis and Knowledge Support System (ReSAKSS).

Gebreselassie A., and Bekele T. 2010. A review of Ethiopian agriculture: Roles, policy and small-scale farming systems. Ethiopia and D. R. Congo.

IUCN. 2010. Wetlands of Ethiopia. Proceedings of a seminar on the resources and status of in Ethiopia's wetlands. The World Conservation Union.

IWMI. 2010. Irrigation potential in Ethiopia. Constraints and opportunities for enhancing the system. International Water Management Institute.

McBratney, A., Whelan, B., and Ancev, T. 2005. Future directions of precision agriculture. Precision Agriculture, 6:7-23.

MoA (Ministry of Agriculture). 2009. Achievements and challenges in Ethiopian agriculture. Addis Ababa, Ethiopia.

MoA. 2011. Small-scale irrigation situation analysis and capacity needs assessment. Ministry of Agriculture, Addis Ababa, Ethiopia.

MoARD (Ministry of Agriculture and Rural Development). 2010. Official documents and records from the Agricultural Extension Directorate. Addis Ababa.

NPC. 2015. The second growth and transformation plan (GTP II) (2015/16-2019/20). National Planning Commission.

ODI. 2015. Building adaptive water resources management in Ethiopia. Overseas Development Institute.

Spielman, D., Alemu, D., and Kelemwork, D. 2013. Seeds, fertilizer, and agricultural extension in Ethiopia. In: Food and agricultural policies in Ethiopia: Progress and challenges, edited by Dorosh and Rashid, 84-122. Philadelphia: University of Pennsylvania Press.

Spielman, D.J., Kelemwork, D. and Alemu, D. 2011. Seed, fertilizer, and agricultural extension in Ethiopia.

Tadele, Y. 2013. Ethiopia: Heineken to set up country's largest brewery. Addis Fortune. http://allafrica.com/stories/201303050013.html.

Teshome, M. 2014. Population growth and cultivated land in rural Ethiopia: Land use dynamics, access, farm size, and fragmentation. Resources and Environment, 4(3): 148-161.

UNDP. 2017. https://www.undp.org/content/undp/en/home/librarypage/hdr/2016-human-development-report.html

Welteji, D. 2018. A critical review of rural development policy of Ethiopia: Access, utilization and coverage. Agriculture & Food Security 7:55 https://doi.org/10.1186/s40066-018-0208-y

World Bank. 2010. Ethiopia public finance review. Report No. 54952-ET, Poverty reduction and economic management, Africa region. Washington, DC. https://openknowledge.worldbank.org/bitstream/handle/10986/12301/549520ESW0P1010IC0disclosed04050120.pdf?sequence=1.