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An Analysis of the use of Chemical Pesticides and their Impact on Yields, Farmer Income and Agricultural Sustainability: The Case for Smallholder Farmers in Ethiopia

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Abstract

In economic theory, the agricultural sector plays an undisputed role in growth, development and poverty reduction in a country. The sector is pivotal for a vast majority of Sub-Saharan Africa (SSA), given the large number of people dependent on agriculture for their livelihood.

With the constraints on land expansion and the dual threat of climate change and an ever increasing population, agricultural productivity has become a key matter of concern in agricultural economics. Given this, a vast majority of literature focuses on improving productivity to meet food demand at any cost. A large percentage of it is focused on the use of pesticides, pre-harvest, to eradicate pests and diseases that lead to losses in the produce. As a result, there has been a significant increase in global pesticide usage over the last few years.

Using the context of smallholder vegetable production in Ethiopia, this paper aims to highlight that although there is a requirement to increase yields to be able to meet the growing food demand, the focus has to shift towards looking at agricultural

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productivity through a sustainable lens. This is to say that increasing the use of pesticides to increase productivity, without considering human and environmental health, quality of produce and farmer income, is not enough to ensure sustainability. Rather, there is a requirement to go beyond the yield-based definition of productivity to incorporate agroecological farming practices.

Keywords: pesticides; smallholders; Ethiopia; yield productivity; agricultural sustainability.

JEL classification: Q15; Q18.

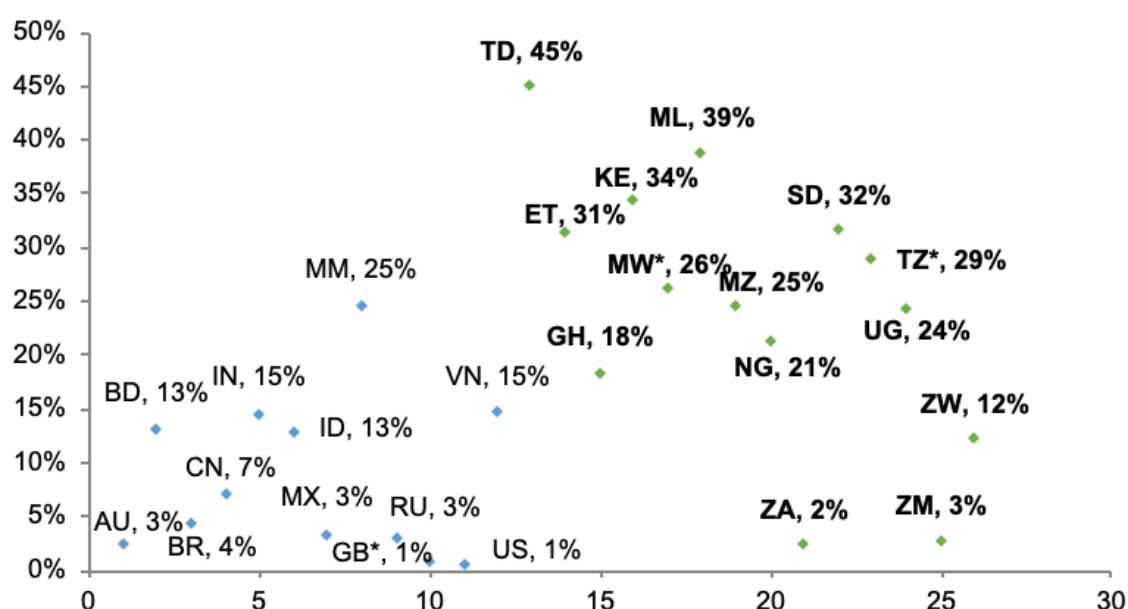
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1. Introduction

The agriculture sector across the globe employs 28 percent of the workforce across 570 million farms, 84 percent of them being small farms (World Bank, 2019). In SSA it is the most important source of economic activity for growth and development, contributing to a high percentage of Gross Domestic Product (GDP) and employment (Figure 1 and 2)^{3 4}. The 2018 WB estimates suggest that global levels of agriculture as a percentage of GDP stands at 3.4 percent, while in SSA, the figure is closer to 16 percent.

Figure 1: Agriculture as a percentage of GDP (2018)

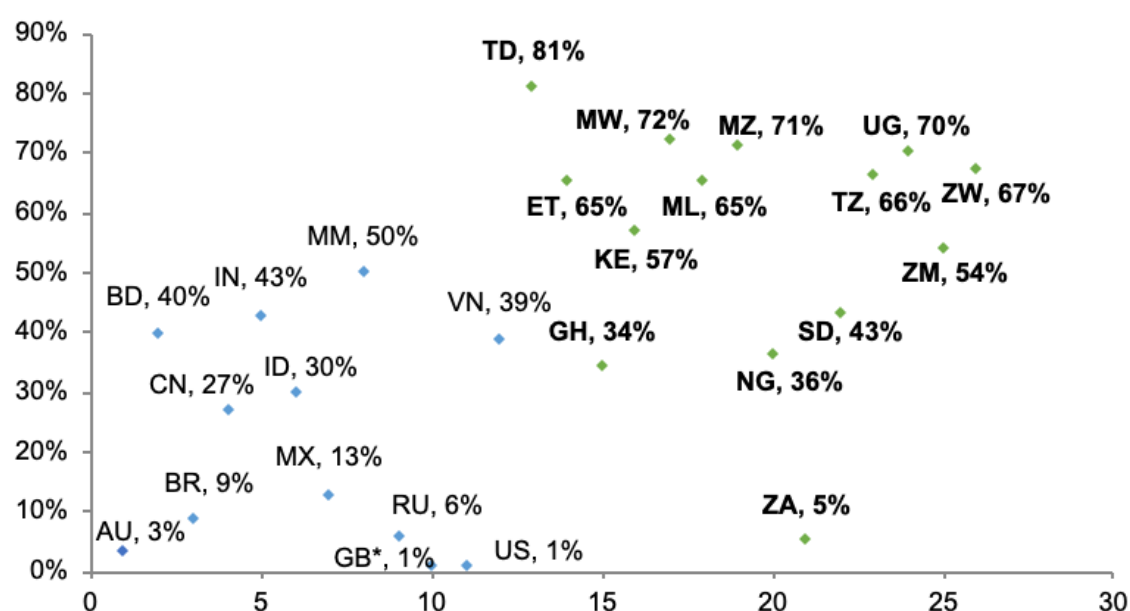


Source: Author's compilation from the World Bank database

³ Figures in bold and green markers are SSA countries. Figures for Great Britain, Tanzania and Malawi are from 2017.

⁴ Annexure 1 lists the countries.

Figure 2: Employment in agriculture as a percentage of total (2018)



Source: Author's compilation from the World Bank database

With a total population of ~1.1 billion people, ~60 percent living in rural areas and 54 percent of the total employed in agriculture, the sector is the main source of livelihood for most of SSA (WB, 2020). Considering its importance for the people and the economy, there have been several efforts by the United Nations (UN), and local governments and organisations to improve the sector in SSA to achieve the UN's Sustainable Development Goal to reach zero hunger by 2030. Increasing climate extremes and variability along with existing pressure on our finite resources to ensure food security has "led to major shifts in the way food is produced, distributed and consumed worldwide" (Food and Agriculture Organisation, 2019a:vii).

In spite of the effort made in reducing global hunger over decades, the progress has stagnated since 2015, after which, according to FAO (2019a), the percentage of people suffering from hunger has remained just below 11 percent (over 820 million people), most of whom live in parts of Africa, Latin America (LATAM) and the Caribbean. Hunger has been on a rise in almost all parts of Africa, with SSA having

the highest levels of undernourishment at ~23 percent (FAO, 2019a). Additionally, there are ~2 billion people in the world that experience moderate or severe food insecurity (FAO, 2019a).

The global food demand is expected to increase significantly till 2050. In addition to fighting for resources with other sectors, climate change adds another dimension to the problems the agriculture sector has to deal with. It has therefore become imperative for economies to focus on improving productivity and efficiency across the sector.

In the case of SSA, despite global efforts to improve efficiency and productivity in agriculture and reduce hunger, the goals are far from being achieved. The region has witnessed a different story compared to both South Asia (SA) and LATAM. In SA productivity grew due to intensification, while in LATAM it was as a result of improvements in labour productivity through mechanisation. In SSA, historical increases in production were credited to “area expansion and intensification of cropping systems, as opposed to large-scale improvements in productivity” (Organisation for Economic Co-operation and Development/FAO 2016:64).

Ethiopia proves to be an interesting case study for agricultural productivity, as despite it being one of the fastest growing economies in SSA, most people still live in rural areas and are heavily dependent on agriculture as their main source of livelihood.

Ethiopia has grown at a rate of 10.5 percent from 2003/04 to 2016/17 and the share of the population living under the national poverty line reduced from ~40 percent in 2004/05 to 24 percent in 2016 (UN Development Programme Ethiopia, 2018). Notwithstanding the impressive growth rate and poverty reduction, Ethiopia remains

a low-income economy and lags behind other nations in SSA in terms of Human Development Index with a per capita income of USD 720 in 2018. Poverty rates in urban areas sharply declined from ~35 percent in 2003/04 to ~15 percent in 2015/16, while in rural areas they declined from ~40 to ~26 percent during the same time period, resulting in poverty predominantly being a rural phenomenon in Ethiopia (UNDP Ethiopia, 2018).

The importance of the agriculture sector in Ethiopia is paramount as estimated by the WB (2020), it contributes to the livelihoods of about two-thirds of the population and over a third of the country's GDP. It is therefore imperative to analyse how the productivity of the sector can be increased, to improve the livelihood of the farmers and food security levels.

Cereals and grains are by far the most important crops for Ethiopia. They not only have the highest percent of area and production (Table 1), but also represent the main diet of the country. Ethiopia, like most low-income countries has a low production and consumption of fruits and vegetables (F&Vs) (Hirvonen, et. al., 2018). The lack of F&Vs in a person's diet leads to several deficiencies in micronutrients, which results in increased presence of diseases amongst the population. Therefore, to ensure food security, there is also a need to produce a sufficient amount of all food groups for domestic consumption.

Table 1: Harvest area and production for major crops in 2018

Crop	Area harvested (as a percent of total)	Production (as a percent of total)
Cereals	47	49
Coarse Grain	39	40
Pulses	7	6
Vegetables	1	3
Fruits	1	2
Others	5	18

Source: Author's compilation from the FAOSTAT database

The productivity of the agricultural sector in Ethiopia remains low, due to the several constraints that the sector faces, including small landholdings, low adoption of farm technologies and mechanisation, poor soil quality, high levels of pesticide and fertiliser usage and low quality inputs.

Ethiopia has been struggling to feed its own population and despite improvements in the sector in the last two decades, food insecurity still impacts 40-50 percent of the country's population (Kelboro and Stellmacher, 2019). Although there has been an increase in the production levels over the last few years, it has been primarily because of land expansion, rather than improvements in the sector. As there is a finite amount of land that can be used for agriculture, Ethiopia now needs to consider how to improve the sector's productivity by moving away from this narrow, yield centric definition of productivity, to a broader one that encompasses environmental, sustainable practices.

The link between higher pesticide usage and increasing productivity has historically not been contested within agriculture. Globally, economies have increased the use of pesticides⁵ to tackle the issue of food lost to pests and diseases. The reduction in

⁵ Refers to synthetic, chemical pesticides.

percentage of food lost, indeed resulted in higher levels of produce at the cost of having chemical residuals contaminating the produce, soil and water (UN, 2017). The adverse impact of pesticides on human, environmental and societal health often comes under the shadow of improving yields (UN, 2017). Additionally, the impact of buying pesticides on farmers' income is rarely taken into consideration.

This study looks at a holistic and sustainable approach to improvements in productivity by weighing agricultural productivity against human and environmental health, and farmer income levels.

Ethiopia traditionally had a high percentage of F&Vs lost to pests and has therefore increased its usage of pesticides. The study summarises the literature on pesticide usage in Ethiopia and goes on to discuss two case studies of the field trials (FTs)⁶ in the Pesticide Action Network (PAN) UK/Ethiopia farmer training centres (FTCs)⁷ in Ziway. These case studies are examples of how the move away from chemical pesticides could be beneficial to smallholder tomato and onion farmers in the region.

The objectives of this study are to:

- a. Highlight the drawbacks of analysing productivity solely as a function of yield.
- b. Highlight the importance of moving away from this traditional definition of productivity.
- c. Assess the impact that pesticide usage has had on agriculture in Ethiopia.
- d. Establish that the use of Integrated Pest Management (IPM) practices is a sustainable way forward for agriculture.

⁶ The FTs refer to the controlled production of tomato and onions in Ziway by the PAN Ethiopia team.

⁷ The FTCs have field sites the size of smallholder farmer fields in the region and are managed by the PAN Ethiopia team.

The structure of the paper is as follows: section 2 is a detailed literature review on agricultural productivity, its definition, link to growth, development, poverty and food security and pesticides, section 3 highlights the background of the case studies, section 4 analyses the case studies and section 5 provides the concluding remarks.

2: LITERATURE REVIEW

2.1 Economic theory and agriculture in developing countries

In economic theory, Lewis (1954) with his dual sector model, was one of the first economists to discuss the role of the agricultural sector in economic development. In his model, the agricultural sector is labour intensive and is characterised with low wages and productivity, while the capitalist sector has high wages, high productivity and is capital intensive. Initially, an underdeveloped economy is dependent on the agricultural sector, and as it develops, labour and capital move towards the capitalist sector. Therefore, the agricultural sector has a passive, but important role in growth and development (Anríquez and Stamoulis, 2007). As a result, there is no need to focus on improving the productivity of the agricultural sector (Onwubuemeli, 1974). Unlike previously believed, the works of Johnston and Mellor (1961) and Schultz (1964), showed that the agricultural sector plays an active role in the growth and development of an economy.

In reality, the dependence on the agricultural sector, both in terms of GDP and employment does reduce as an economy develops (Fisher (1939) and Kuznets (1957) discuss this). However, given that the sector lies in the heart of developing economies, employs a high number of people and contributes to GDP, the progress in promoting economic growth, reducing poverty and enhancing food security cannot be achieved without developing the agricultural sector (FAO, 2002).

Across all developing countries the agriculture sector is similar in terms of its features. It consists of farmers with small landholdings farming for subsistence. These farmers are uneducated and have access to poor quality of extension services and training (FAO, 2002). The problem that the sector faces is the low production, owing to low levels of productivity. Further, there is a widespread lack of

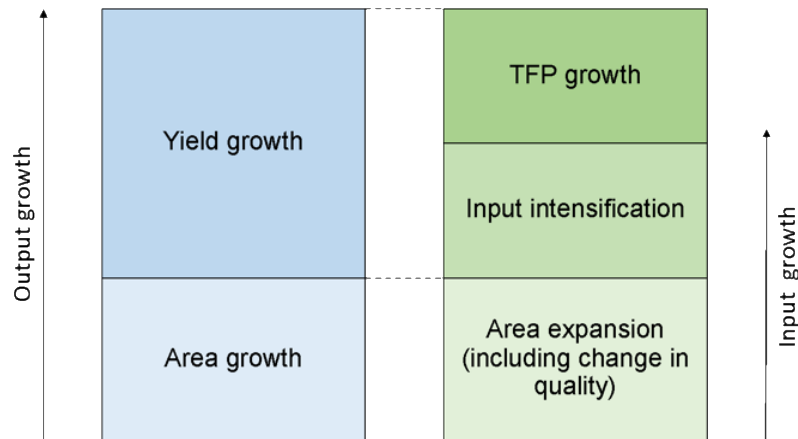
infrastructure which makes it difficult for the few larger farmers with a surplus to access markets to sell their produce.

Low productivity is not only a function of small-scale agriculture and the number of people involved in farming, but also "primitive technologies, poor organisation, and limited physical and human capital inputs" (West, 2002:51). Traditionally, production is increased by increasing the area of cultivation, changing the inputs and technology. Today's developing countries do not have the option of increasing the area of cultivation and therefore are left with having to improve inputs and technology, both of which are expensive and often unaffordable for smallholder farmers (SHFs).

2.2 Defining agricultural productivity

In economics, productivity "measures the ability to produce by employing factors of production and resources" (OECD, 2016:15). Although there is no universal definition of productivity in agriculture, Zepeda (2001) suggests the most commonly used definitions are total factor productivity (TFP) or in partial terms through labour productivity and yield (output per worker or hectare respectively). Figure 3 shows how TFP growth is calculated - the difference between output and input growth (Fuglie, 2014).

Figure 3: Breakdown of TFP growth



Source: Fuglie (2014)

This figure comes from the Cobb-Douglas production function (Equation 1), where Y is output, A is technology, K is capital and L is labour.

$$Y = AF(K, L) \quad \text{Equation 1}$$

Taking the total differential of Equation 1, decomposes output in terms of its inputs (Equation 2).

$$dY = AF_K dK + AF_L dL + F(K, L) dA \quad \text{Equation 2}$$

Equation 2 can be re-written as shown in Equation 3 below, where a is capital's share in output and $(1-a)$ is labour's share in output and g_A is the growth in output that is not explained by inputs and is designated as technological progress or TFP and is the residual (Boianovsky and Hoover, 2009). These models are based on general equilibrium and they lack the ability to incorporate endogenous changes to productivity, as TFP is assumed to be exogenous (Abro, et. al., 2014).

$$g_Y = ag_K + (1 - a)g_L + g_A \quad \text{Equation 3}$$

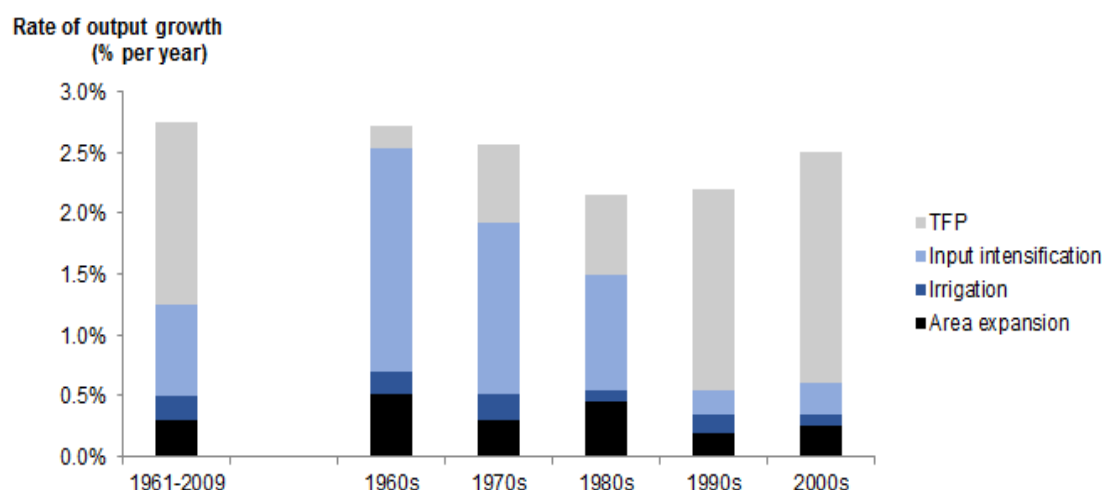
Labour productivity and yield do not give a complete picture of productivity, however, given that expanding resources for agricultural purposes is not always an option, output growth in the agriculture sector becomes solely dependent on improvements

in yield. As a result, economists have traditionally focused on yields to improve the performance of the sector, thereby making this partial definition of agricultural productivity important.

2.3 Growth of agricultural productivity

Fuglie, et. al. (2012) show that globally TFP has replaced input intensification and area expansion to become the main contributor to agricultural growth (Figure 4). In the 2000s, TFP contributed to more than 75 percent of agricultural growth. In terms of regions, the TFP growth more than doubled between the 1960s-1990s during the Green Revolution (GR) and increased more than three times during this period.

Figure 4: Primary components of agricultural growth



Fuglie, et. al (2012)

The GR of the 1960s and 1970s led to increases in agricultural productivity in several Asian and a few LATAM economies, however, this was not replicated in the same manner in SSA. As shown in Table 2, TFP rates increased during the 1960s and 1970s in all regions except SSA, where TFP rates reduced from 0.17 to -0.05 percent.

Table 2: Agricultural TFP growth rates by region

Region	1960s	1970s	1980s	1990s	2000s
Sub-Saharan Africa	0.17%	-0.05%	0.76%	0.99%	0.51%
Latin America & Caribbean	0.84%	1.21%	0.90%	2.30%	2.74%
Asia	0.91%	1.17%	1.42%	2.30%	2.74%
West Asia & North Africa	1.40%	1.66%	1.63%	1.75%	1.88%

Source: Fuglie, et. al (2012)

Block (1994) was one of the first to analyse agricultural productivity in SSA. His study showed that 39 SSA countries experienced negative TFP growth rates during the 1970s and positive growth rates in the 1980s. Lusigi and Thirtle (1997) found similar results for 47 African countries. The TFP in these countries grew by 1.27 percent per year between 1961 and 1991, with no signs of productivity growth in the 1960s and 1970s. This was later backed by the findings of Fulginiti, et. al. (2004), who estimated that TFP rate grew by 1.29 and 1.62 percent per year in 41 SSA countries between 1960 and 1999. Byerlee, et. al. (2005) also suggest productivity levels increased during this time. However, the TFP levels in a majority of African countries remained low compared to other regions, which was due to labour shortages, climate, increasing costs of inputs, poor irrigation, lack of access to capital and markets (Byerlee, et.al., 2005).

Findings of Fuglie (2010) show that although there was an increase in agricultural output during the timeframe mentioned, most of the output growth came from expanding crop land rather than improvements in productivity. Additionally, although Nin-Pratt and Yu (2008) confirm the increase in TFP since the 1980s, they found that TFP growth between 1964 to 2003 shows an annual growth of -0.15 percent. This means that improvements in the 1980s were merely making up for the significantly negative TFP growth rate during the 1960s and 1970s.

2.4 Link between agricultural productivity, poverty, growth and development

The agriculture sector provides food for sustenance and also plays an additional role in reducing poverty, as many of the world's poor live in rural areas and depend on it as a source of livelihood (WB, 2019). Therefore, the argument of improving agricultural productivity, reducing poverty and increasing growth and development in an agriculture based economy is a rarely debated one (WB, 2007). The theoretical argument is that improvements in agriculture will automatically lead to reductions in poverty through the trickle-down effect, as a result of increasing farm incomes and falling food prices. This would have a direct impact on rural poverty, through increasing incomes and an indirect impact on urban poverty, by the reduction in food prices.

(Anríquez and Stamoulis, 2007) and Irz, et. al. (2001) summarise the main channels through which the agriculture sector reduces poverty. (Anríquez and Stamoulis, 2007) discuss two channels: the direct impact of the growth and improvement in agriculture leading to an increase in income and consumption of SHFs, and the indirect impact which can be categorised into three factors. First, the reduction in food prices due to improvements in productivity, increasing the real income of the rural poor as the majority of their income is spent on food. Second, the increase in the incomes of the non-farm rural community, which is dependent on the sector. Third, an increase in employment and wage of labour, due to the growth in the sector. Irz, et. al. (2001) adds a few more channels and focuses on the impact on the farm, rural and national economy (Table 3).

Table 3: Pathways of poverty reduction

Farm Economy
Higher incomes from farm output
More on-farm employment due to an increase in labour demand, area of cultivation and therefore increase in farm wage rate
Rural Economy
More jobs upstream and downstream in agriculture and food value chains
More jobs or higher incomes in non-farm economy as farmers & farm labour spend their additional income
Increased income and employment allow better nutrition, health and increased investment in education leading indirectly to higher labour productivity
Generates more local tax revenue and demand for better infrastructure, contributing to second round effects promoting the rural economy
Linkages in production chain generate trust and information, build social capital and facilitate non-farm investment
National Economy
Reduced prices of food and raw materials raises real wages of the urban poor, reduces wage costs of non-farm sectors
Generation of savings and taxes from farming allows investment in non-farm sector, creating jobs and incomes in other sectors
Earning of foreign exchange allows import of capital goods and essential inputs for non-farm production
Release of farm labour allows production in other sectors

Source: Anríquez and Stamoulis (2007) and Irz, et. al. (2001)

In practice, the GR successfully showed increasing agricultural productivity led to poverty reduction, economic growth and development. Several Asian and a few LATAM economies, during this time, went through structural transformations⁸ due to improvements in agriculture. During the same time, there was a significant reduction in poverty and an increase in growth rates. In SA, between the mid-1980s and early 2000s, yields increased by more than 50 percent and poverty reduced by more than 30 percent (WB, 2007). In the case of India, “higher agricultural wages and higher yields reduced rural poverty, and that they do so with about the same elasticity. It is higher yields combined with higher wages that matter” (Datt and Ravallion, 1998:14).

⁸ Moving away from agriculture and towards manufacturing and services.

Additionally, Ahluwalia (1978), using two decades of data from the GR, showed a statistically significant relationship between rural poverty and agricultural performance in India. Similar results have also been shown for the case of China (Ravallion and Shaohua, 2007 and Fan et. al., 2005), Indonesia (Thorbecke and Jung, 1996) and Mexico (Lopez-Acevedo and Saavedra, 2005).

After the success of the GR, there was an increased focus on agriculture and its importance on development in the 1970s and 1980s (Christiaensen and Demery, 2007). However, “the agriculture-led transformation of Asia has not been replicated in Africa” (Byerlee, et. al., 2005:1) and in the 1990s resulted in questions around “agriculture’s potential to reduce poverty” (Christiaensen and Demery, 2007:2). In the beginning of the 1980s, the poverty levels in East Asia (EA), SA and SSA were similar, at 58, 52 and 42 percent respectively. At the turn of the century, these figures were at 15, 31 and 48 percent respectively. At the same time, cereal yields increased by 50 and 68 percent in EA and SA while it reduced by 15 percent in SSA. Although these figures do not show a causal link between cereal yields and poverty, there is a requirement for policy makers to consider that the agriculture sector contributes to the economic growth and development of a region (Christiaensen and Demery, 2007).

In rural Ethiopia, where the majority of the poor reside, agriculture is the main source of livelihood and therefore improvements in agricultural growth and productivity would lead to an increase in rural incomes and thereby a reduction in poverty. The country is an interesting case study that shows this link. This is because the Ethiopian government has made significant public investments into the sector to help it grow and therefore act as a means of transformation in the economy. However, according to Abro, et. al. (2014) the rapid increase in population growth has

dampened the effect of the agricultural growth and has not had the desired impact on the economy.

For two decades, starting in 1995, the Ethiopian economy has focused on an agricultural development-led industrialisation (ADLI), which defines “increasing land yields as a precondition for successful industrialisation, urbanisation and development and, given the country’s egalitarian land distribution, favourable distribution effects” (UNDP, 2017:28). This strategy was promoted alongside market-led, state-supported policies with a focus on investments in rural infrastructure development and poverty reduction. Under ADLI, there was a move towards promoting the commercialisation of small-scale farmers and with these interventions, Ethiopia has reduced its Gini coefficient from 0.3 in 1995 to 0.28 in 2011 (UNDP, 2017).

2.5 Agricultural productivity and food security

Food security is a growing concern across the world and there is a need for the agricultural sector to improve significantly to meet the growing demand for food for the increasing population. According to UN estimates, the world population will reach 9.7 billion by 2050. The majority of this population increase will arise from nine developing countries⁹ accounting for 50 percent of this population increase. At the same time, Dumas, et. al. (2018) estimate, the global food demand would increase by 56 percent. This increase in demand for food needs to be met with an increase in agricultural productivity by moving towards sustainable farming practices, ensuring minimal adverse impact on the environment.

⁹ India, Nigeria, Pakistan, Democratic Republic of Congo, Ethiopia, Tanzania, Indonesia, Egypt and United States of America.

Edward et. al. (2019) found that there is a link between sustainable practices and improvements in productivity. Using a comprehensive watershed-level sustainable land management programme, they showed that the yields of certain crops, like maize and finger millet increased by 18-19 percent. Aggregating all crops, they also found a 9 percent increase in the incomes of farmers who were part of this programme.

There is limited literature focusing on the aspect of efficiency in the supply chain post-harvest and its impact on food security. Currently, post-harvest, over a third of the food produced in the world goes to waste, either in the form of food loss or food waste. FAO defines food loss and food waste as the decrease in the quantity or quality of food resulting from decisions and actions of the food suppliers in the chain and of the retailers, food service providers and consumers respectively. The amount being wasted is enough to feed another 2 billion people, however, there are 820 million people in the world that remain in hunger (FAO, 2019a).

The literature is focused on the relationship between productivity and food security, which stresses on increasing productivity in terms of yields to increase production, to meet the growing demand for food. Although food security cannot be discussed without taking productivity into consideration, there is a dire need to change the angle from which productivity is analysed. There is a need to move away from only measuring yields, towards a broader definition of productivity which encompasses agroecological, global best farming practices, post-harvest losses and nutrition.

2.6 Pesticide usage among SHFs in SSA and Ethiopia

Since the 1940s, the use of pesticides to treat pests and diseases has been encouraged to improve productivity and reduce the level of production lost

(Mengistie, 2016). The FAO (2019b) estimates 20-40 percent of global crop production is lost to pests each year, as a result of which, there is an increased use of pesticides to reduce this pre-harvest loss to pests, enough to feed the equivalent to 1 billion people globally (Bharucha and Pretty, 2015). From the sole view of food security, the use of pesticides to reduce the loss of crops to pests on the surface seems like a viable option. However, the use of pesticides led to several additional problems and there is now a requirement to reduce pest damage without increasing the costs associated with synthetic pesticides (Bharucha and Pretty, 2015).

Globally there has been an increase in the non-targeted pesticide use to control pest infestations. As a result, pests are becoming increasingly immune to common pesticides and natural predators of pests are being destroyed (Tisdell and Wilson, 2001). Additionally, this has led to higher levels of environmental degradation and virulence among a large number of crops increasing the risks to farmers and consumers, raising the question of agricultural sustainability (Tisdell and Wilson, 2001).

Tisdell and Wilson (2001) find three main reasons why pesticides are encouraged by market forces. First, there is ignorance towards their sustainability - pesticides are often perceived to be more sustainable than they actually are. Second, they are an integral part of the high yielding variety of seeds (like the ones used during the GR), wherein without the use of pesticides, high yields would not be achieved. Third, chemical companies selling these pesticides encourage its use in production. As a result, “chemicals in agriculture may be encouraged in preference to the use of natural ingredients available to farmers on farms.” (Tisdell and Wilson, 2001:457).

The current level of pesticides used in Africa is the lowest in the world (Table 4), however, this figure does not take into account the type, quality of pesticides and the

lack of awareness around handling and usage. Pesticides, if not handled cautiously and used properly, are detrimental to the environment as well as human health (Negatu, et. al., 2016). Residuals of the pesticides contaminate the soil, water and crops, thereby entering the production and food chains, leading to human and animal consumption (Mengistie, 2016 and UN, 2017). The amount of pesticide used varies by crop, but several studies have shown that the amount used in the production of F&Vs is the highest across the world and is true for Ethiopia as well.

Table 4: Pesticide usage in 2017 (in kilograms per hectare)

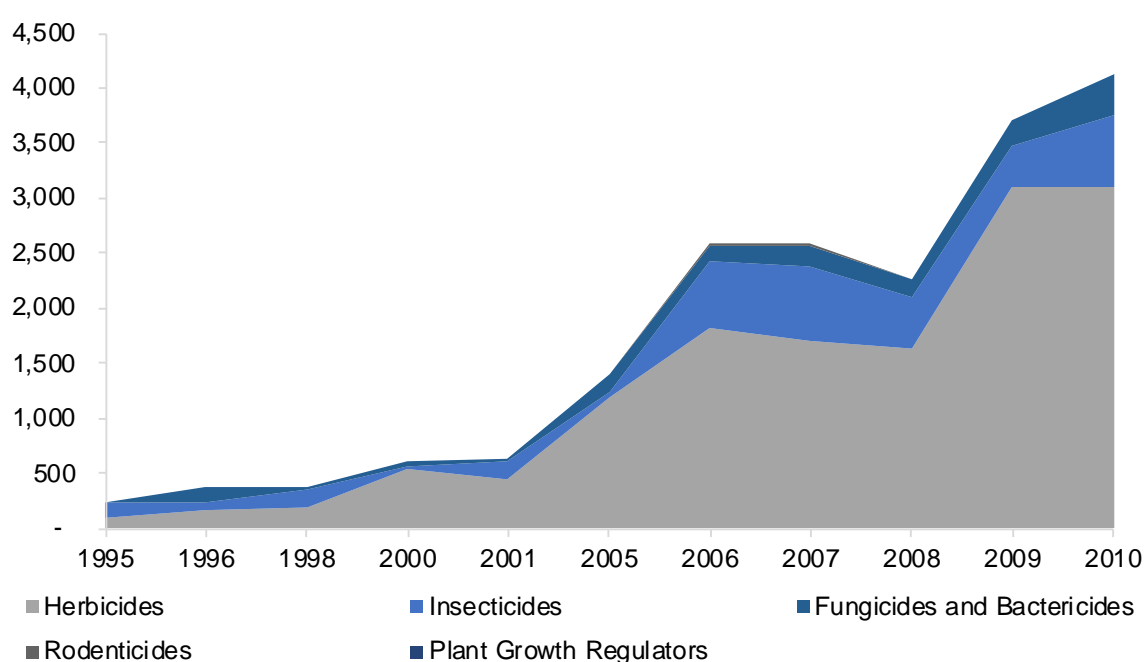
Region	Pesticide usage (kg/ha)
Africa	0.29
Eastern Africa	0.20
Ethiopia	0.24
Americas	3.57
North America	2.51
South America	5.42
Europe	1.65
Oceania	2.09
Caribbean	1.74
Asia	3.67
South Asia	0.31
South East Asia	1.15
East Asia	12.74
World	2.63

Source: Author's compilation from the FAOSTAT database

Looking at the pesticide usage in Ethiopia, although significantly lower than the world average (Table 4), has increased over the years (Figure 5). The increase in the use

of pesticides is a result of the growing food insecurity in Ethiopia which requires increases production (Negatu, et. al., 2016).

Figure 5: Pesticide breakdown by type in Ethiopia (1995-2010)



Source: Author's compilation from the FAOSTAT database

In Ethiopia, pests and diseases are a major bottleneck to ensuring food security as the total amount of produce lost to them stands at 30-40 percent, and for vegetables, this figure is between 24-49 percent (Mengistie, 2016). Ngowi, et. al. (2007) shows that in Tanzania onion, tomato and cabbage farmers use the highest amount of pesticides. Ball, et. al. (2008), using data from four countries, found that vegetable farmers reported the highest frequency of pesticide application.

Farmers in Ethiopia reported that pesticides were the most expensive input in tomato and onion production. Although this paper disproves this farmer perception in the analysis section, it is important to focus on pesticides as inputs, as they have the potential to reduce costs for farmers thereby increasing incomes. As a result, going forward, this paper looks at the problems with pesticide usage in Ethiopia, case studies of tomato and onion production in Ziway in a controlled environment and provides conclusions regarding more sustainable production practices and a more inclusive definition of productivity.

2.6.1 Pesticide and regulation

While the use of pesticides in developing countries is lower than developed ones, the pesticide distribution and use is not as well regulated (Jansen, 2008). Most of the 302 pesticides used in Ethiopia fall under Class II of the WHO hazard classification system (Mengistie, 2016). The lack of knowledge and regulation surrounding pesticide use has led to a misuse of pesticides in Ethiopia (Mengistie, 2016). Additionally, pesticides being the most expensive input for farmers, leads to them buying cheaper pesticides which are harsher and more hazardous and can be used for all insects (Mengistie, et. al., 2017).

SHFs often buy these chemicals from informal vendors, traders and peddlers, who do not correctly label the chemicals. For example, in Ethiopia, informal traders “decanted insecticides into empty penicillin vials or scraps of plastic, without labelling” (Ball, et. al., 2008:1330). Farmers do not have concerns regarding the “toxicity, residue effects, environmental impacts or risk/benefits for themselves or consumers” (Mengistie, et. al., 2017:317).

The Ethiopian government is aware of the risks that come along with the increase in the use of pesticides, and therefore implemented a pesticide risk-reduction programme between 2010-2015 (Bråtveit, et. al., 2020). This programme focused on strengthening pesticide registration and management, specifically looking at sustainability and human health. Although a comprehensive programme, did not help in reducing the amount of pesticide used in production and was not focused on the environmental problems that arise due to the use of pesticides (Bråtveit, et. al., 2020). There is therefore a need to focus on alternatives.

2.6.2 Poor practices

Several studies recognise that farmers often follow poor pesticide use practices in SSA. Farmers often follow a “calendar-based” spraying pattern, “without consideration of pest incidence or level of attack” (Ball, et. al., 2008:1329). Additionally, Cissé, et. al. (2008) show that in Senegal less than a third of farmers reported applying pesticides on the basis of the crops showing symptoms of pests while Singbo, et. al. (2008) find in Benin, the factors that influenced pesticide application were the gender of the farmer, irrigation method and the type of crop and not the recognition of pests.

Mengistie, et. al. (2017) found that there is a lack of knowledge and training on the amount and frequency of pesticide use. For example, over 70 percent of farmers did not bother reading the pesticide labels while only 8 percent of farmers surveyed were able to read and understand the pesticide labels correctly. Additionally, in terms of pesticide training and support, more than 87 percent of farmers had received no prior training/technical support on pesticide use and handling (Mengistie, et. al., 2017), while Negatu, et. al. (2016) found that only 15 percent of farmers had received formal training in pesticide hazards. In addition to this, Dinham (2003), finds that poor education, poverty and lack of extension services contribute to poor practices around pesticide use, rather than farmers being ignorant.

All this has led to issues in the health of both the farmers and consumers of the produce (Bon, et. al., 2015, Ball, et. al., 2008 and Ngowi, et. al., 2007). These poor practices have also led to the loss of the environment and lowered the quality of soil, water, etc., having adverse effects on agricultural production (Bon, et. al., 2015).

2.6.3 Lack of non-chemical practices

Many papers have analysed the pesticide usage trend and have found that the use of non-chemical methods for pest management¹⁰ was very limited. Negatu, et. al. (2016) found that only 10 percent of farmers used biopesticides and 8 percent used IPM, as alternatives to chemical pesticides. The rising pesticide sales are as a result of “weak regulatory control and the lack of an IPM oriented national policy framework countries” (Popp, et. al., 2013:252).

IPM, as defined by the FAO, is “an ecosystem approach to crop production and protection that combines different management strategies and practices to grow healthy crops and minimise the use of pesticides.” According to Bharucha and Pretty (2015) IPM can be of several forms. First, by substituting pesticides with other compounds, which have a lower toxicity or are agrobiological or biopesticides. Second, management and application of pesticides, like targeted spraying. Third, releasing predators to control the pest population. Fourth, agroecological habitat design, for example seed and seed bed preparation, crop rotation, etc.

IPM has been successfully implemented in a range of crops and agro-climatic zones (Maredia, et. al., 2003). IPM practices are aimed at addressing long term sustainability of crop production through preventing pests and diseases from becoming resistant to frequently used chemicals and leveraging natural pest control processes (biological methods using natural enemies) as well as reducing human and environmental harm.

Bharucha and Pretty (2015) analysed data for over twenty years from 85 IPM projects in 24 countries in Asia and Africa which showed yields increased by ~40

¹⁰ Not synthetic, purchased pesticides.

percent and at the same time, the use of chemical pesticides reduced by ~30 percent compared to the baseline study. These figures prove that across crops and agroclimatic zones, there is a benefit to switching away from pesticides towards IPM techniques of pest and disease management (PDM).

As mentioned earlier in the paper, most studies conducted on agriculture in Ethiopia focus on grains, as it is the main produce in the country. This paper adds to this literature by analysing the trend in the usage of pesticides in the F&V sector, focusing on tomato and onions. Additionally, as is the case with several other low income countries, the consumption of F&Vs is very low (Hirvonen, et. al., 2018). However, to ensure food security¹¹ in Ethiopia, there is a requirement for the country to focus on other food groups outside cereals.

This paper therefore argues a move away from pesticides to a more sustainable IPM approach, incorporating human and environmental health. It further suggests that by adopting sustainable practices, farmers would have the potential to reduce their production costs as well as increase their earnings from the produce, by selling higher quality produce in the markets. The case studies in Section 4 show that if smallholder tomato and onion farmers in Ziway adopt these IPM methods of production used in the FTCs, they have the potential to lower costs, increase yields and their incomes.

¹¹ Which is not just focused on the quantity of food, but also the quality and nutrition levels of food, ensuring a well-balanced diet.

3: BACKGROUND ON FARMER CASE STUDIES

PAN is the only charity in the UK focused on tackling the problems caused by pesticides. Their aim is to eliminate the use of hazardous pesticides, reduce dependence on pesticides and promote the use of ecologically sustainable alternatives to pesticides¹².

The data that has been used for the paper is from the PAN UK/Ethiopia FTs in the Central Rift Valley (CRV) area in Ethiopia¹³. The data is from three FTs, two during the Meher season (June to September 2018 and 2019) and one during the Belg season (February to May 2019). The purpose of the FTs was to analyse whether the IPM techniques that have proven to be successful for cotton production in Ethiopia can be used to act as pest control methods and reduce the use of chemical pesticides for F&V production as well.

The CRV area in Ethiopia, specifically around Lake Ziway (Figure 6), is one of the few freshwater ecosystems in the country, with a significant ecological importance due to the richness and diversity of the region. Lake Ziway also has a high level of economic importance, with fishermen and small scale and commercial farmers being dependent on it.

¹² <https://www.pan-uk.org/about-us/>.

¹³ Annexure 3 and 4 has the detailed data for the tomato and onion FTs respectively.

Figure 6: Map of Ethiopia and Ziway



Source: Google Maps

In recent years, however, there is an increasing threat to this region as a result of agricultural intensification around Lake Ziway. This has led to deforestation, soil erosion and degradation, environmental pollution and increasing risks to human health. According to the baseline survey¹⁴ conducted by PAN UK/Ethiopia for this project, there has been an increase in the use of and dependence on agrochemicals by farmers in the region, due to the lack of awareness regarding pest management options available. Mengistie, et. al. (2017) also showed that other means of crop

¹⁴ PAN UK/Ethiopia and ISLA (2018). Supporting Healthy, Sustainable and Productive Smallholder Vegetable Farming: Final Baseline Survey Report.

protection such as IPM and/or biological control were not practiced by farmers in the Ziway region in Ethiopia.

This baseline study was conducted in 2018 and was used to decide the crops and areas for the IPM field trials. The survey was conducted in five villages Aluto, Abein Deneba, Abine Germama, Bochessa and Edo Gojola in the CRV of Ethiopia, where vegetables are widely grown by SHFs, with most farmers producing onions, cabbage and tomatoes.

The major findings from the baseline study showed that the pesticide usage on a majority of farms was poorly informed, wasteful and excessive, as farmers had limited knowledge of PDM and IPM practices. Additionally, conventional farmers applied pesticides more frequently than needed by applying either on a calendar basis or every time they enter the crop for hoeing, regardless of the level of pests and/or diseases.

In 2019 PAN UK/Ethiopia conducted a survey¹⁵ on a small number of farmers (15) in the region that had received the Global Good Agricultural Practices (GGAP) training, which also corroborated the findings from the 2018 baseline survey. Despite having been trained in the GGAP, all of these farmers use chemicals as their sole PDM method. Few farmers reported knowing the active ingredients (AIs) in the chemicals they use qualify under the PAN International highly hazardous list of chemicals¹⁶ (10 of the 18 used). These farmers still had limited or no understanding of biological or alternative products for PDM. This survey showed that GGAP trained farmers and other SHFs have similar knowledge in terms of PDM, therefore there was no reduction in the use of hazardous chemicals.

¹⁵ PAN UK/Ethiopia and ISLA (2019). Preliminary Results of the Project Survey of Global GAP Certified Farmers.

PAN UK/Ethiopia found that pesticide usage was higher than the recommended amount (specifically agrochemicals) in the production of onions and tomatoes despite being one of the largest costs. Farmers in Ethiopia have “little tolerance for pest infestation” and therefore rely heavily on the use of pesticides (Mengistie et. al., 2017:302).

This paper focuses on case studies of the FTs using the primary data collected from onion and tomato production in the FTCs in Edo Gojola and Bochessa by PAN Ethiopia¹⁷.

Table 5: Description of the three treatments of the FTs

Treatment	Description
T1 – Food Spray	The use of food spray as pest management and neem spray and a softer insecticide, when required ¹⁸ .
T2 – Neem Spray	The use of neem spray as pest management.
T3 – Conventional	Chemical control plot using a more rational PDM regime compared to typical nearby SHFs.

For the purpose of this paper, the data was analysed to see the impact the use of pesticides has on yields, quality of produce and farmer income. Farmer income was calculated on the basis of total revenue minus total costs¹⁹. The total costs included the cost of land preparation, transplanting, inputs (nutrients, seedlings, pest and disease control), irrigation, cultivation, harvesting and labour. The FTs also encompass the amount and frequency of each of the treatments for PDM.

¹⁶ <https://www.pan-uk.org/highly-hazardous-pesticides/>

¹⁷ Tomato FT1 and FT3 were conducted in Bochessa and FT2 was conducted in Edo Gojola, while for onion, FT1 and FT3 were conducted in Edo Gojola and FT2 was conducted in Bochessa.

¹⁸ Neem spray was added into food spray solution if previous food sprays fails to keep damaging pests below control and pest balance became highly unfavourable. Additionally, tracer would only be used in the case where both the neem and food spray failed.

¹⁹ All figures for cost, revenue and farmer income are mentioned in Ethiopian Birr (1 USD = ~33.5 Birr)

The analysis of the data from the FTs is used to show that IPM practices tend to have higher yields, better quality produce and reduced costs of pesticides, all of which result in higher incomes and are more sustainable.

4: ANALYSIS AND DISCUSSION

The primary data collected by PAN UK/Ethiopia is discussed in the form of two case studies in this section. The first case study analyses the tomato FTs and the second one evaluates the onion FTs.

As mentioned in Table 5 in section 3, there were three methods tested and analysed for the tomato and onion FTs. The first being the food spray trial, which is a natural/biological pest control method that helps increase the number of natural enemies in crops. The food spray is made from yeast, which attracts predatory natural enemies like ladybirds and beetles. These natural enemies consume the pests that occur in the crops, thereby ensuring lower numbers of damaging pests such as aphids, leafhoppers and bollworms.

The cheap chemical insecticides used in Ethiopia do not focus on controlling specific insects and as a result, damage all insects, including natural enemies. Using the food spray method, the FTs aimed to see whether the different treatments could deliver broadly similar pest levels. Even if the pest levels were higher in T1 compared to T3, the damage to the produce was not necessarily higher, as there were lower levels of chemicals in the produce.

The neem spray is the second trial, which is used mainly to understand the existence of pest and natural enemy incidences in the absence of pesticides, unlike the food spray it does not attract a higher number of natural enemies towards the crops. PAN UK/Ethiopia gathered the required information about this method after the first two FTs and therefore did not conduct a FT for the third season.

The third trial, conventional method, represents a less intensive approximation of the typical smallholder farming practices in the region. This method uses the traditional pesticides as the method for PDM.

4.1 Case study 1: Tomato FTs

The graphs in Figures 7, 8 and 9 show the breakup of total costs by PDM. The break-up of the costs are as follows:

- PDM: biological and chemical insecticides (food and neem spray, profit²⁰ and tracer²¹) and fungicides (baking soda, mancozeb, ridomil gold²², altracol, copper oxychloride).
- Labour costs: land preparation, transplanting, cultivation and harvesting.
- Soil fertility and poly feed: biological and chemical fertilisers (manure, urea, NPS, DAP).
- Input costs: seedlings, material and fuel for irrigation.

As shown in Table 6 in FT1, tomatoes grew without the use of insecticides in both the food and neem spray methods, while in FT2, T1 required one round of insecticides and T2 required none, and finally in FT3, T1 required the use of two rounds of insecticides. For T3, the number of rounds of insecticides applied is far lower than the results PAN UK/Ethiopia received from the baseline study (at least 10). This shows that the requirement of even the pesticides is far lower than what is currently being practiced by SHFs in the region.

The AIs in the insecticides used during the FTs are profenofos and spinosad. Both these ingredients are listed on the PAN highly hazardous list of pesticides. They are considered to be detrimental for the environment, specifically impacting bees.

²⁰ Profenofos is the AI.

²¹ Spinosad is the AI.

²² Metalaxyl and Mancozeb are the AIs.

Table 6: Frequency of the PDM – tomato²³

Parameters	Pest control			Disease control		
	T1	T2	T3	T1	T2	T3
FT1	FS: 10	NS: 10	I: 9	F: 6	F: 6	F: 12
FT2	FS: 7, NS: 2, I: 1	NS: 7	I: 6	F: 5	F: 5	F: 5
FT3	FS: 4, NS: 3, I: 2	N/A	I: 5	BS: 3, F: 6	N/A	F: 6

Source: PAN UK/Ethiopia data

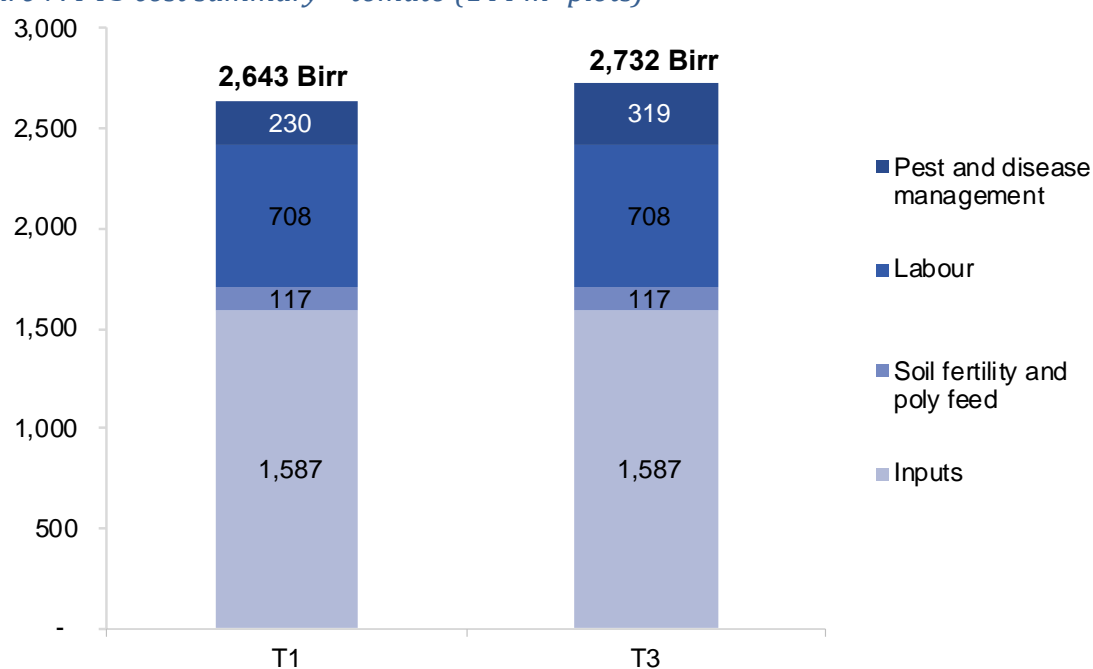
All costs, except for the costs of PDM are the same for each of the methods within each of the three FTs. Therefore, the difference that arises in the total costs is only a result of the PDM costs. All three Figures (7, 8 and 9) show that the costs for T3 are the highest among all methods, which is due to the method using chemical inputs for pest control, which are most expensive.

Even within PDM, the disease management is the same between the treatments. Only in FT1 there were more rounds of chemical disease management in T3, which was subsequently reduced in the next trials, as it was not required. Therefore, this confirms that the main difference between the treatment methods is the pest control costs.

In the first two FTs there were no biological disease management trials that were conducted and the same fungicides were used across each treatment. While analysing FT3 it should be noted that baking soda was used as a partial replacement for the chemical fungicides in T1.

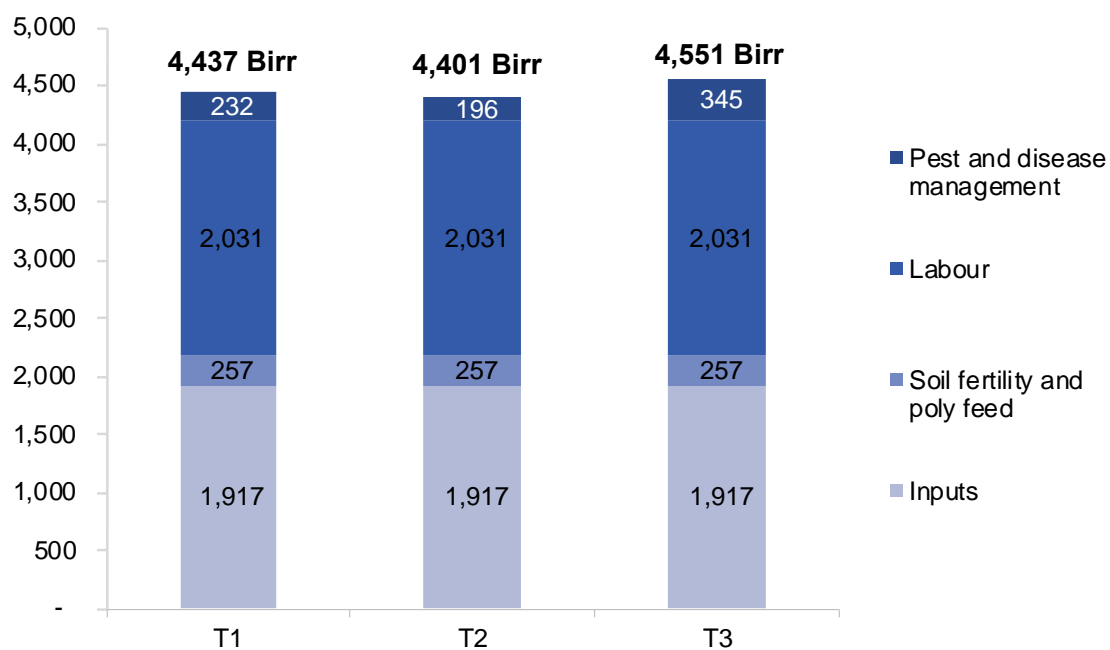
²³ FS: food spray, NS: neem spray, BS: baking soda, I: insecticides and F: fungicides.

Figure 7: FT3 cost summary – tomato (144 m² plots)



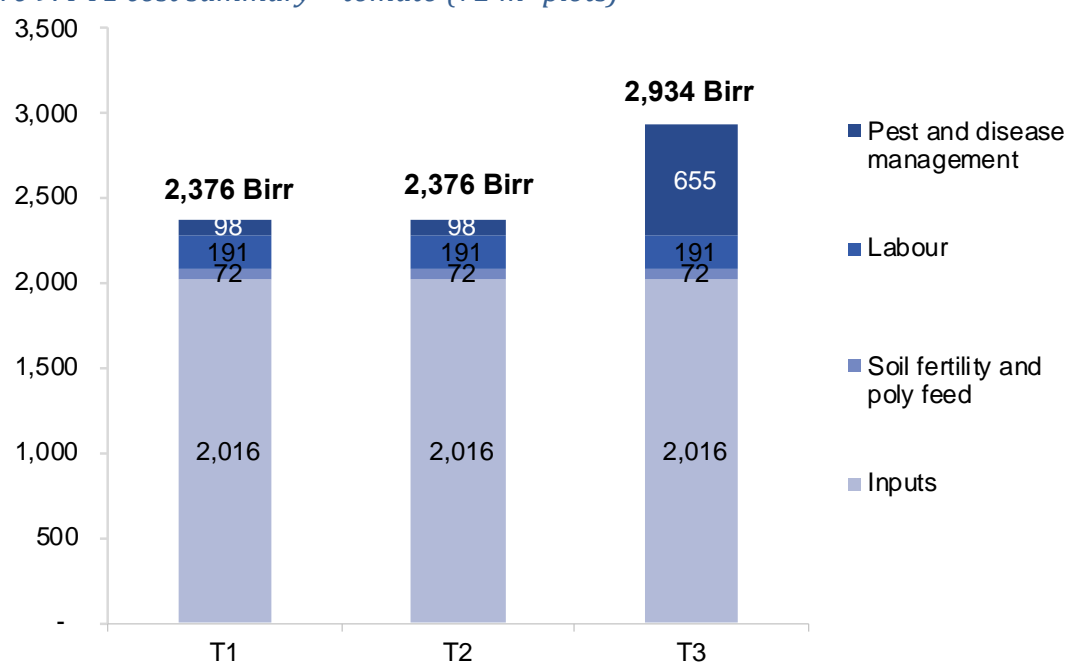
Source: PAN UK/Ethiopia data

Figure 8: FT2 cost summary – tomato (225 m² plots)



Source: PAN UK/Ethiopia data

Figure 9: FT1 cost summary – tomato (72 m² plots)

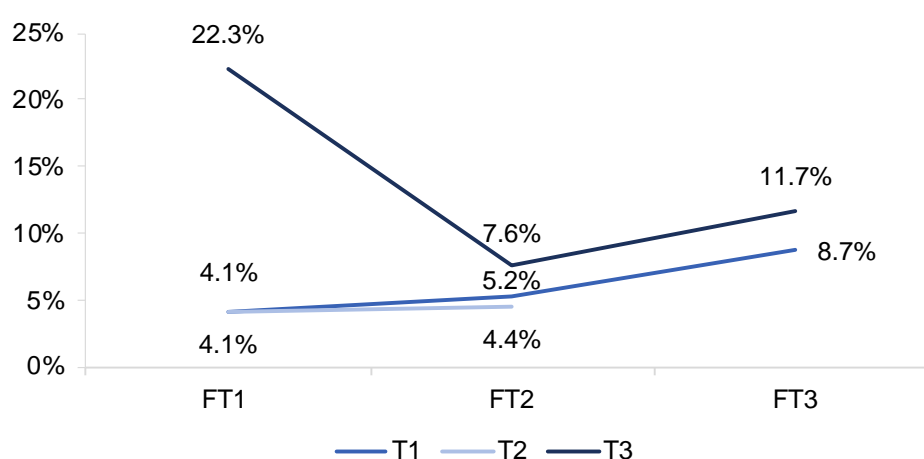


Source: PAN UK/Ethiopia data

The plot size for FT1 T1 and T2 was 72 m² and for T3 was 60 m². The values mentioned in Figure 9 for T3 have been adjusted to 72 m² to be able to compare the values between the methods.

As shown in Figure 10 the PDM costs for each of the FTs is higher in T3 compared to both T1 and T2. The data in Figure 10 is the cost of PDM as a percent of total cost for the plot size (adjusted to 72 m²).

Figure 10: PDM costs as a percentage of total cost – tomato



Source: PAN UK/Ethiopia data

All three seasons²⁴ of the FTs revealed that the number of natural enemies present in T1 were higher compared to the other treatments, while over the FTs, there were differences in the total number of pests observed across treatments. The main natural enemies found in the tomato trials included predatory ladybirds, spiders, ants, hoverflies and lacewings.

As previously mentioned most SHFs in the region have traditionally based their PDM on the basis of a calendar, or as soon as they witness the first insects on the crop, without considering that some insects are actually beneficial. For T1 to be viable across SHFs, they would require training to be able to distinguish the natural enemies from the pests, as a high number of natural enemies are present. Without which, farmers would think that this higher number of insects means their crops are suffering more and would increase the dosage and frequency of pest control. However, what would not be considered is how the presence of natural enemies

²⁴ Data for FT1 and FT2 have shown this, and it is expected that the data for FT3 will show similar results.

protect the crops, as they kill harmful pests. This is shown by the higher and similar yields in T1 compared to T3 in FT2 and FT3 respectively (Table 7)²⁵.

In terms of marketability of produce, T1 had a higher and similar levels to that of T3 in FT2 and FT3 respectively. For FT1 it is important to note that they are outliers, as there were changes in the project staff during the trials, which contributed to less attention being paid in the early symptoms of pests and diseases and the lack of timely control measures along with poor soil quality and growing conditions in Bochessa. This caused lower yields and the higher percentage of unmarketable fruits that year. FT2 shows that the unmarketability of T1 and T2 was significantly lower than T3. This was due to the health of the tomatoes across the rounds of picking, which also contributed to the lower yields in FT2 for T3 compared to T1 and T2. FT3 shows a significant increase in the marketability of produce across both T1 and T3.

The yields mentioned in Table 7 are calculated for 0.25 hectares on the basis of the actual yields in the FT plots. This was done to be able to compare between the treatment methods and the FTs. The unmarketable produce is the percentage of produce that was damaged and could not be sold as a percentage of the total produce from the actual plot size.

Table 7: Yield and unmarketable fruits – tomato

Parameters	Yield (kg/0.25 ha)			Unmarketable (%)		
	T1	T2	T3	T1	T2	T3
FT1	3,090	3,368	4,729	40.7	26.8	12.3
FT2	8,667	7,478	4,633	7.0	8.1	22.2
FT3	16,458	N/A	16,458	0.4	N/A	0.3

Source: PAN UK/Ethiopia data

²⁵ There is a correlation between the number of natural enemies and yields, however there are other agronomic, biological and weather factors which might lead to differences in the yields.

It is not enough to look at just the marketability of the produce. For example, in FT1, T3 had a significantly lower percentage of unmarketable fruits, however, as shown in Table 8, the farmer income is almost the same. The result can be seen clearly in Figure 10, which shows the profit per kilogram of tomato produce. For FT1, this figure for T1, T2 and T3 was -1.0, -0.2 and -1.7 respectively. Therefore, despite a significant amount of produce not being marketable, the loss per kilogram of tomatoes was lower in T1 and T2 compared to T3. This is a direct result of the PDM costs being higher in T3 compared to T1 and T2.

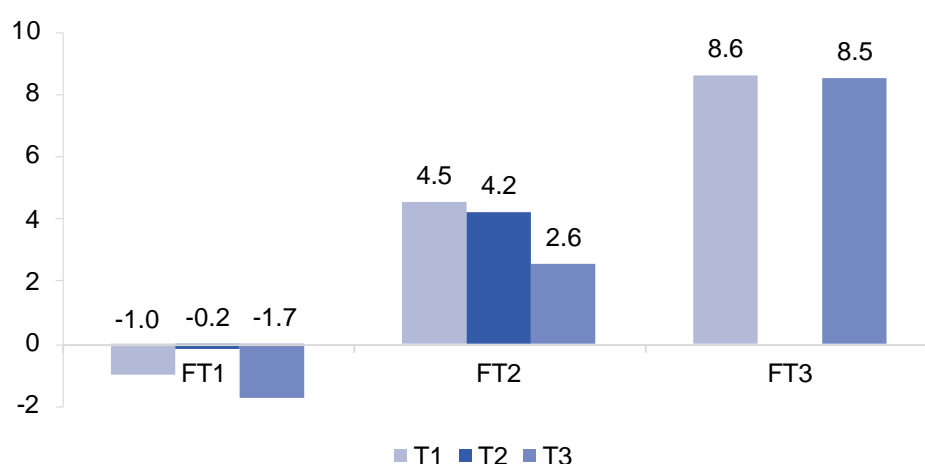
Table 8: Total cost, revenue and farmer income for 0.25 hectare – tomato

Parameters	Cost			Revenue			Profit		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
FT1	29,274	29,274	48,155	26,265	28,628	40,197	(3,009)	(646)	(7,959)
FT2	15,559	15,458	16,591	54,911	47,222	28,600	39,352	31,765	12,009
FT3	23,105	N/A	24,575	164,583	N/A	162,847	141,478	N/A	138,272

Source: PAN UK/Ethiopia data

The data in Table 8 shows the cost, revenue and profit for 0.25 hectare, which have all been calculated from the actual plot size for each FT. It should also be noted that the site for FT2 is different to that of FT1 and FT3, and as a result there might be differences in the cost.

Figure 11: Profit per kilogram of produce for 0.25 hectare – tomato



Source: PAN UK/Ethiopia data

Figure 11 shows the profit per kilogram of tomatoes produced for 0.25 hectares to be able to compare it across treatments and FTs and was calculated using the actual plot size for each treatment. There has been an improvement in the profitability across all treatments from FT1 to FT3.

The most important conclusion from this graph is that the profitability for T3 is lower when compared to both T1 and T2 for all the FTs, as a result of the costs being higher for T3. From this it can be deduced that if the food spray method is adopted by SHFs in the region, they would be able to achieve similar levels of yields to their current practices and also have the potential to increase their incomes. Additionally, they would be practicing more sustainable, agroecological methods of PDM.

4.2 Case study 2: Onion FTs

As shown in Table 9 in the first FT, onions grew without the use of insecticides in both the food and neem spray methods, while in the second FT, T1 required two round of insecticides and T2 required none and finally in the third FT, T1 required the use of one rounds of insecticides. For T3, the number of rounds of insecticides applied is lower than the results PAN UK/Ethiopia received from the baseline study (6-11). This shows that the requirement of pesticides is far lower than what is currently being practiced by SHFs in the region. The AIs in the insecticides are the same as the ones used by the tomato farmers.

Table 9: Frequency of PDM – onion

Parameters	Pest control			Disease control		
	T1	T2	T3	T1	T2	T3
FT1	FS: 9, NS: 1	NS: 9	I: 11	F: 4	F: 4	F: 12
FT2	FS: 5, NS: 1, I: 2	NS: 5	I: 6	F: 4	F: 4	F: 4
FT3	FS: 3, NS: 3, I: 1	N/A	I: 4	BS: 2, F: 3	N/A	F: 5

Source: PAN UK/Ethiopia data

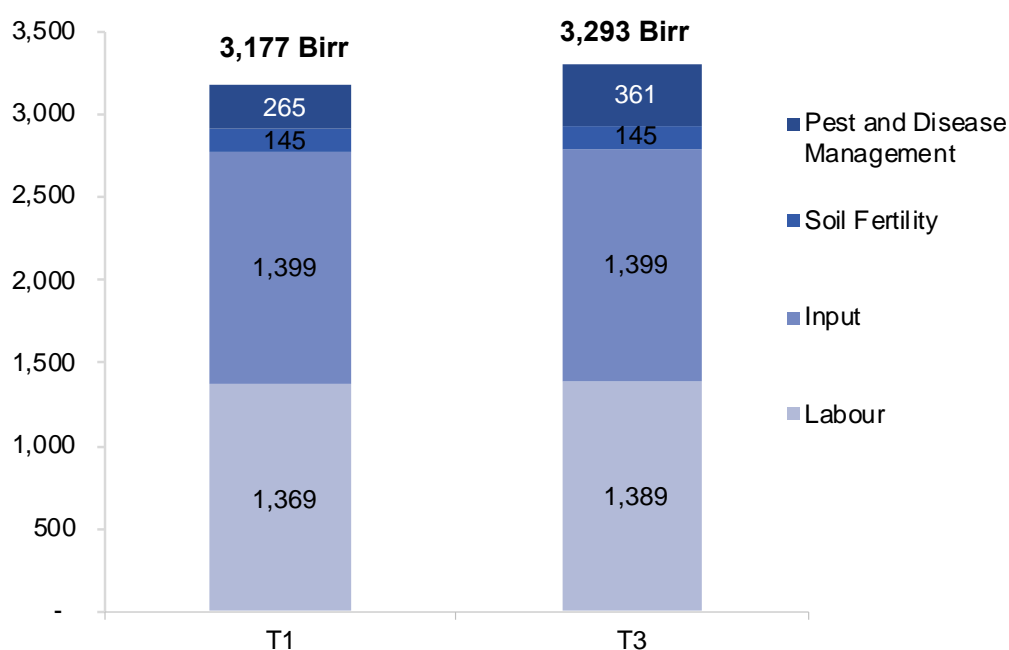
The PAN UK/Ethiopia team was only able to collect the actual costs of PDM from the onion farmers in Edo Gojola for FT1. Therefore, as a substitute all costs, except for the PDM costs, mentioned in the graphs and tables below for FT1 for the plot size (144 m²) have been calculated from the data collected for the production costs from the baseline study that the PAN UK/Ethiopia team conducted in 2018.

Similar to the tomato FTs, all costs, except for the costs of PDM are the same for each of the treatments. Therefore, the difference that arises in the total costs is only a result of the PDM costs. Figures 12, 13 and 14 show that the total costs for T3 are

the highest, which are again a result of farmers using chemical pest control methods rather than biological ones.

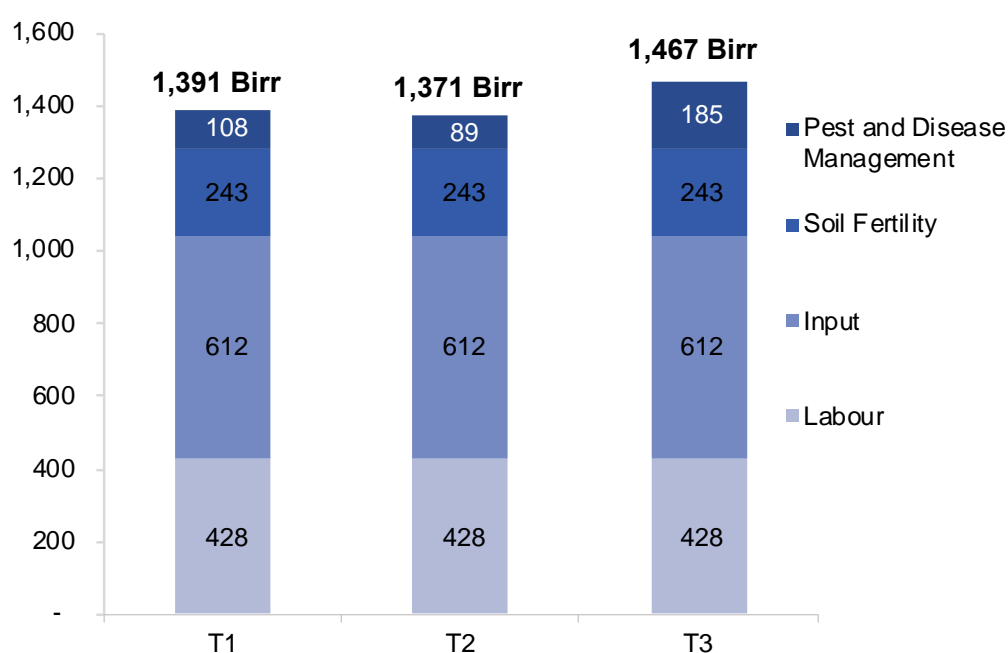
As is the case with the tomato FTs, within PDM, disease management is similar across all treatments, except in FT3, wherein the PAN UK/Ethiopia team added baking soda as a biological disease management solution. In FT1 disease management was higher for T3, on par with nearby SHFs. However, in the later trials, the use of fungicides reduced, as it was not required. This shows two main findings – first, SHFs are spraying their produce with chemical PDM inputs more than required and second, the main difference in the costs between the methods is in the pest management costs.

Figure 12: FT3 cost summary – onion (225 m² plots)



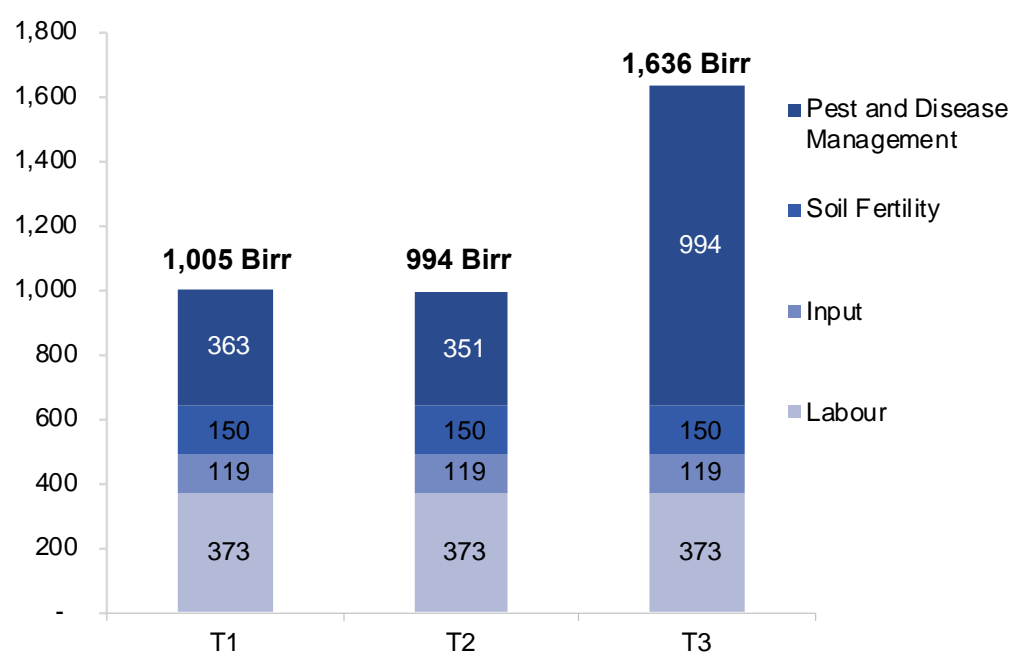
Source: PAN UK/Ethiopia data

Figure 13: FT2 cost summary – onion (156 m² plots)



Source: PAN UK/Ethiopia data

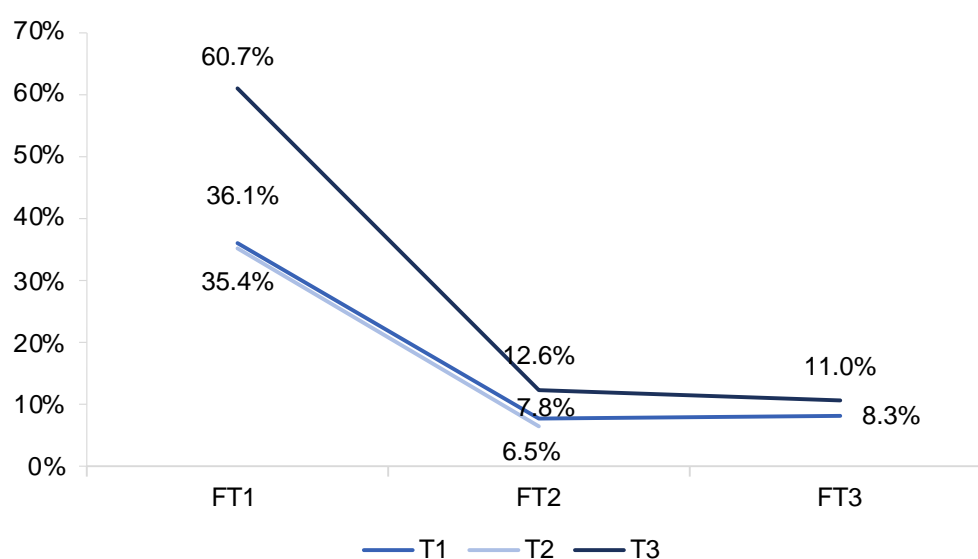
Figure 14: FT1 cost summary – onion (144 m² plots)



Source: PAN UK/Ethiopia data

As shown in Figure 15, the PDM costs for each of the FTs is higher in T3 compared to both T1 and T2. The data shown in Figure 15 is the actual cost of PDM as a percent of total cost for the actual plot size for each of the FTs.

Figure 15: PDM costs as a percentage of total cost – onion



Source: PAN UK/Ethiopia data

The main natural enemies observed in the onion crop were ladybird beetles, ants, spiders, hoverflies and earwigs. For all three FTs, there were a higher number of natural enemies found in T1 when compared to T3²⁶. As is the case for the tomato FTs, SHFs in the region would require training to identify the difference between the insects in terms of natural enemies and pests, in order to use the food spray method of pest control effectively. Similar to tomato FTs, the natural enemies in the onion FTs, have contributed to T1 having similar yields to that of T3 (Table 10).

All the three treatments have similar yields and marketability rates across the FTs, which are higher compared to those of nearby SHFs. This could be contributed to the use of biological pest control for T1 and T2 and better PDM practices for T3²⁷. The yields mentioned in Table 10 are calculated for 0.25 hectare on the basis of the actual yields in each FT plot.

²⁶ Data for FT1 and FT2 have shown this, and it is expected that the data for FT3 will show similar results.

²⁷ Frequency and type of pesticide application.

Similar to the results of the FT1 of tomato, the lower yields of FT2 of onion across all treatments could be attributed to the poor growing conditions in terms of soil quality, weather and the number of pests in the FTC in Bochessa.

Table 10: Yield and unmarketable fruits – onion

Parameters	Yield (kg/0.25 ha)			Unmarketable (%)		
	T1	T2	T3	T1	T2	T3
FT1	7,483	7,890	8,958	3.0	2.6	2.9
FT2	962	833	1,587	0.0	0.0	0.0
FT3	4,186	N/A	5,444	0.0	N/A	0.0

Source: PAN UK/Ethiopia data

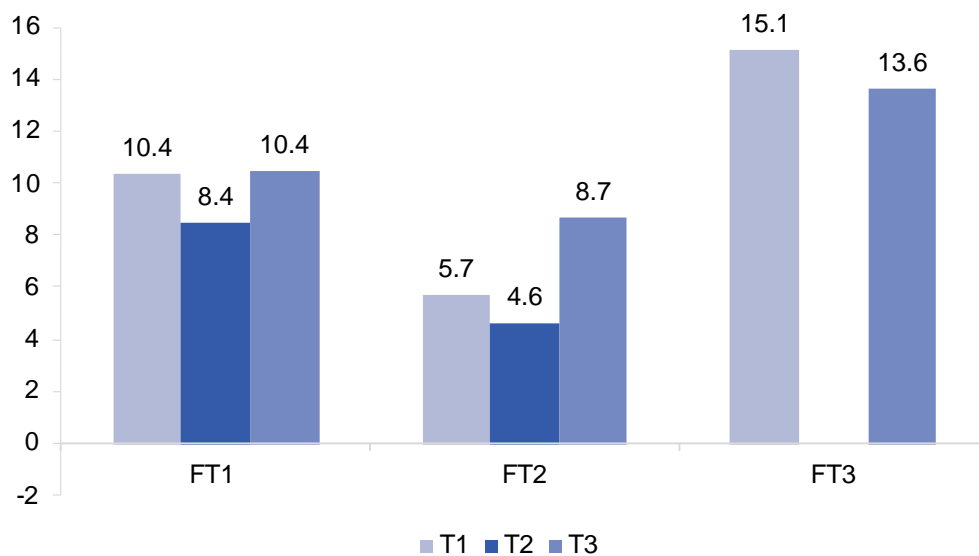
Table 11: Total cost, revenue and farmer income for 0.25 hectare – onion

Parameters	Cost			Revenue			Profit		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
FT1	8,853	8,553	10,053	86,342	75,217	103,373	77,490	66,665	93,320
FT2	8,853	8,553	10,053	14,303	12,380	23,798	5,450	3,827	13,745
FT3	18,883	N/A	20,045	82,019	N/A	74,186	63,138	N/A	74,186

Source: PAN UK/Ethiopia data

The data in Table 11 shows T3 to be most profitable for onion production amongst the three FTs. However, when considering the level of profit per kilogram of onion produced for 0.25 hectare, T1 has had a higher profit for FT1 and FT3. Despite the yields being lower in T1 compared to T3, the food spray did help with pest control, as all the produce was marketable, which is an important result.

Figure 16: Profit per kilogram of produce for 0.25 hectare – onion



Source: PAN UK/Ethiopia data

From Figure 16 it can deduce that if the SHFs in the region adopt the food spray method, they have the potential to make higher profits for every kilogram of onions they sell. Even though the T3 method has a higher yield, the amount of profit per kilogram of produce is lower in FT3 and almost equal in FT1 to the biological pest control method (Figure 16). Finally, as is the case for tomato farmers that adopt the IPM methods, if T1 is adopted by smallholder onion farmers, they would be practicing more sustainable and agroecological methods of production.

4.3 *Key Findings and Policy Discussions*

From all the figures and tables above for both the tomato and onion FTs, there are several conclusions that can be derived.

First, the typical smallholder tomato and onion farmers in the Ziway region use pesticides more frequently and spend more money on them compared to the control group of the FTs in the T3 method. Regardless of whether farmers adopt biological inputs or not, there is a requirement for them to reduce the amount and frequency of their usage of chemicals for pest control.

Second, the FTs for T1 and T2 spend less money on pesticides compared to T3 and significantly lower compared to the nearby conventional SHFs. The use of the food spray attracts natural enemies, which should be a part of a more sustainable IPM solution, rather than the sole use of highly hazardous pesticides. This emphasises the need for SHFs in the region to move towards non-chemical inputs as pest control to reduce their cost of production.

Third, the use of the food spray led to higher yields for the tomato FTs and yields that were on par with the conventional methods for the onion FTs. It should be noted that it is difficult to make any robust consultations between seasons due to the natural variability and the way in which the costs were estimated.

Fourth the quality of the produce was higher in T1 compared to T3 for tomatoes and on par with T3 for onions.

Fifth, the reduction in chemical residues in produce has the potential to improve the quality of the lives of farmers and their households, consumers and reduce the risk of environmental degradation.

The results for the three FTs for all treatments strongly suggest that moving towards more sustainable approaches using food spray and IPM practices is economically feasible and sustainable for SHFs producing tomatoes and onions in Ziway, without compromising on the yields or the quality of their produce. The case studies show that IPM methods have the potential to deliver higher yields, quality and profits, if managed properly. Most SHFs are unable to afford the rising input costs of chemical pesticides and therefore the switch towards IPM practices would lower their upfront input costs and would be an added incentive.

As previously mentioned, the FTs were conducted in the PAN Ethiopia FTCs and were managed by the PAN Ethiopia staff. SHFs part of the PAN UK/Ethiopia farmer field schools in the region visited these FTCs in FT2 and FT3 to discuss, understand and learn about the IPM practices. According to a preliminary survey conducted on 30 SHFs, by PAN UK/Ethiopia in February 2020, they are able to see the benefits of and are eager to make the switch towards IPM methods of pest control. Additionally, compared to the baseline survey conducted by the team, most farmers (98 percent) have understood the difference between the types of insects and the use of natural enemies. These results are promising are due to the training SHFs, part of the farmer field schools, received by the PAN Ethiopia team. However, for SHFs to successfully implement these practices on their fields and scale up, government intervention is required.

As a result of this, there is a requirement for governments and other policy makers to focus on other aspects of productivity to improve the state of the agriculture sector, rather than just the yields. Although beyond the scope of this study, in order to be able to make agroecological production a reality, there is a requirement to improve

the supply chain post-harvest as well, which can only be achieved through positive policy support from the government.

The recent release of the WB's 'Enabling the Business of Agriculture 2019' report highlights the importance of regulatory policies across the agricultural value chain for improvements in the sector. The report goes beyond the discussions around yields and analyses whether government regulations and policies facilitate or hinder agriculture.

The Enabling the Business of Agriculture (EBA) score takes into consideration eight quantitative indicators²⁸ across the agriculture value chain. Ethiopia ranked 73 of the 101 countries analysed for this study. The report showcases a link between a sound regulatory environment and improvements in yields, reductions in poverty and undernourishment, which for a low income, agriculture dependent country like Ethiopia is invaluable.

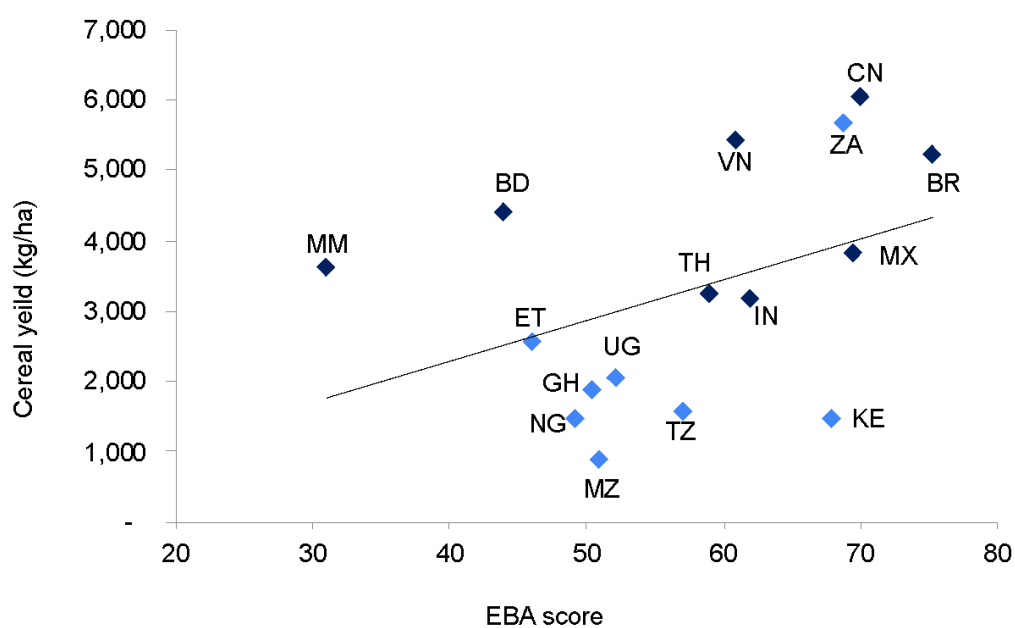
The three Figures (17, 18 and 19)²⁹ show the link between the score and the three indicators mentioned above for Ethiopia and a select few countries³⁰.

²⁸ Supplying seeds, registering fertilisers, registering machinery, sustaining livestock, protecting plant health, trading food, accessing finance and securing water.

²⁹ The light blue marker represents SSA countries.

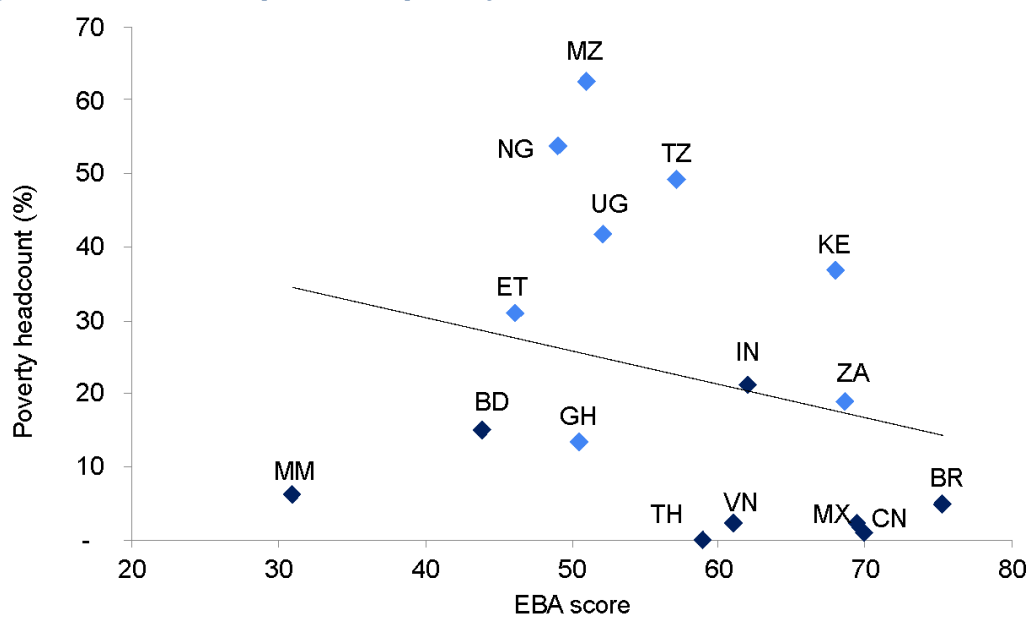
³⁰ Annexure 2 lists the countries.

Figure 17: Relationship between cereal yields³¹ and EBA score



Source: Author's compilation from the World Bank EBA report

Figure 18: Relationship between poverty³² and EBA score

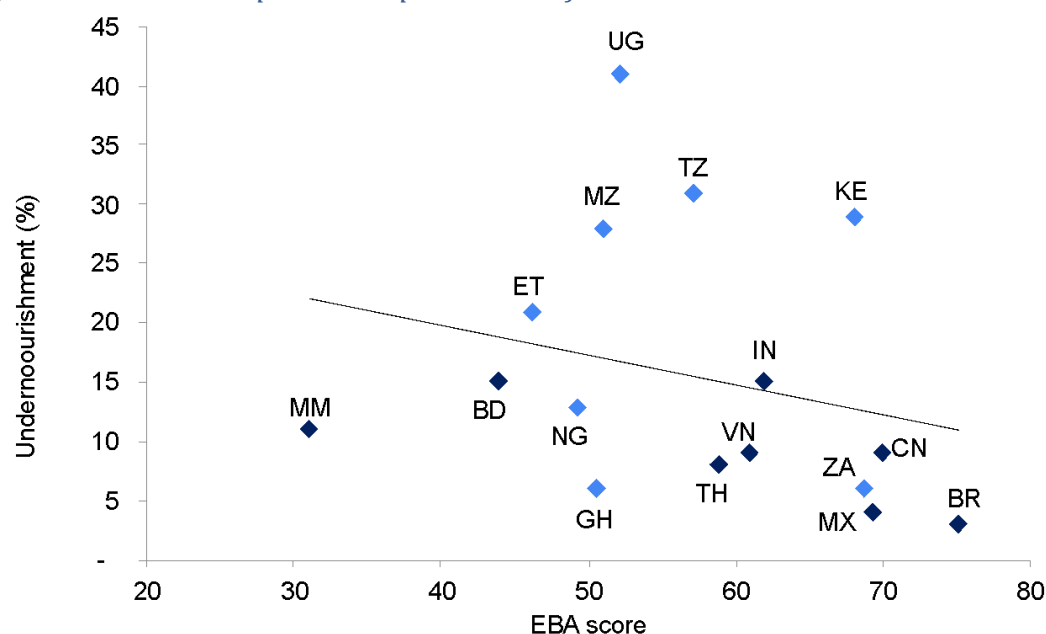


Source: Author's compilation from the World Bank EBA report

³¹ Yield figures are from 2017.

³² Poverty headcount ratio at USD 1.90 / day (2011 PPP)

Figure 19: Relationship between prevalence of undernourishment³³ and EBA score



Source: Author's compilation from the World Bank EBA report

The findings from this EBA report show that if governments and policy makers focus on improvements across various aspects of the agriculture sector and move away from just discussing yields, there is scope to significantly impact the sector. A sound regulatory environment has the potential to not only have a positive impact on the sector but also on the growth, development, poverty and food security levels in an economy.

³³ Prevalence of undernourishment figures are from 2017.

5: CONCLUSION

Economic theories on agriculture and evidence from the GR in Asia showed that there is a requirement for policy makers to improve the productivity levels in the agricultural sector. The policies and practices used during the GR were unable to replicate the success of Asia in the same capacity in SSA. This paper aims to argue against the sole emphasis on improving agricultural yields to improve productivity in the sector.

Focusing on the increase in pesticide usage in Ethiopia as a means to increase yields of agricultural produce, this paper attempts to show how yield is a small part of the larger productivity picture, which encompasses farmer incomes, sustainable farming practices in addition to yields.

The tomato and onion case studies prove to be a good example of how moving away from pesticides has the potential to reduce costs, increase yields and incomes and by definition, reduce the amount of chemical residue in the produce of SHFs in Ziway. This in turn has the potential to significantly improve human (farmer and consumers) and environmental health. Additionally, this model of using food sprays to attract natural enemies as pest control has the potential to be replicated across crops and smallholder farms in Ethiopia. This then has the potential to improve the lives of many SHFs across the country, which would in turn reduce poverty and food insecurity as well as lead to higher growth and development.

Although the data from the FTs in Ziway has been successful in showing advantages of using biological pest control methods, further research into the impact of the IPM practices on yield, farmer income and quality of produce is required to be able to sufficiently conclude that expanding these practices across crops in Ethiopia will lead to similar results.

Additionally, using data from the FTs to calculate farmer incomes for 0.25 hectares shows better results, there is also a requirement to conduct these trials on larger farms to be able to conclusively suggest that IPM practices are more suited and profitable for all farm sizes.

Continuing these FTs in Ziway on tomato and onion SHFs as well expanding to larger landholdings and a variety of crops would provide for irrefutable evidence for making a move away from pesticides. This is an urgent step to take because of the fast changing environment and rapidly growing population, both of which are putting pressure on the agricultural sector to feed the population in the future. On the basis of this it becomes imperative for governments and other policy makers to intervene and analyse the viability of sustainable farming practices on a large scale.

ANNEX 1

List of countries from Figure 1 and 2

AU: Australia

BD: Bangladesh

BR: Brazil

CN: China

TD: Chad

ET: Ethiopia

GH: Ghana

GB: Great Britain

IN: India

ID: Indonesia

KE: Kenya

ML: Mali

MW: Malawi

MX: Mexico

MZ: Mozambique

MM: Myanmar

NG: Nigeria

RU: Russia

ZA: South Africa

SD: Sudan

TZ: Tanzania

UG: Uganda

US: United States

VN: Vietnam

ZW: Zimbabwe

ZM: Zambia

ANNEX 2

BD: Bangladesh

BR: Brazil

CN: China

ET: Ethiopia

GH: Ghana

IN: India

KE: Kenya

MX: Mexico

MZ: Mozambique

MM: Myanmar

NG: Nigeria

ZA: South Africa

TZ: Tanzania

TH: Thailand

UG: Uganda

VN: Vietnam

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