ADDIS ABABA UNIVERISTY
SCHOOL OF GRADUATE STUDIES

THE PRODUCTIVITY & PROFITABILITY OF WHEAT AND TEFF TECHNOLOGIES IN SELECTED VILLAGES OF ETHIOPIA

BY

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A THESIS PRESENTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIRMENTS FOR THE DEGRE OF MASTERS OF SCIENCE IN ECONOMIC POLICY ANALYSIS

June 2001

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School of Graduate Studies

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BY
Nigussie Tefera

Approved by the Board of Examiners:

Mulat Demeke ______________________ ______________________

Advisor Signature

Gezahegn Ayele ______________________ ______________________

Examiner Signature

Workneh Negatu ______________________ ______________________

Examiner Signature

Acknowledgment

I wish to extend my sincere gratitude to all individual who assisted me during the preparation of this study.

Above all, I am very indebted to my advisor Dr. Mulat Demeke for his professional excellent advice, guidance and constrictive comment. I have benefited not only from his ample experience and suggestions but also his constant supply of relevant materials.

Special thanks are due to my girlfriend, Tirsit Eshetu and her families for unreserved moral and material support that they rendered to me from the beginning to the end of this study. I am thankful to my parents, brothers, and sisters for their moral support. I am particularly grateful to W/ro Tenagne Demissie, Dejene Tefera, W/ro Asnakech Tefera, and Alemtsehay Tefera for their continuous moral encouragement. Special thanks are due to Colonel Belaineh Taye, Ato Mekbib Aderaye Ato Taddese Biru, Peter Tefera and Shewangizaw for spending their valuable time in commenting and reading my theses. My appreciation are also directed to W/ro Selamawit Aderaye, Ato Mengiste Tamir, Ato Mesay Taddese, Ato Alemayehu Taddese, Ato Zelalem Taddese, Abaynesh Teddese, Almaz Eshetu, Marta Eshetu, Rahel Eshetu, Hilina Eshetu, Etsubdenk Yemanebrehan, Abera Adugna, Ayelech G/Hiwot, Ato Teddle Gatenh, Ato Befirdu Woldamanueal, Ato Masresha Yilma, W/ro Yibralem Desta, Meskrem Zelalem and Furnus Dejene for their valuable moral supports.

Once again, my heartfelt gratitude goes to Dr. Mulat Demeke, Dr. Tigist Demeke, W/ro Salamawit Aderaye and W/ro Alem Bezu for the many support they have provided me for the last two years without which I probably could not have completed the M. Sc program.

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Synonyms

ADD	= Agricultural Development Department.
ADDP	= Ada District Development Project.
ADLI	= Agricultural Development Led Industrialization.
AMC	= Agricultural Marketing.
ARDU	= Arssi Regional Development Unit.
CADU	= Chillalo Agricultural Development Unit.
EMTPs	= Extension Management Training Plots.
FDRE	= Federal Democratic Republic of Ethiopia.
GDP	= Gross Domestic Product.
HYV	= High Yielding Varieties.
IAR	= Institute of Agricultural Research.
IFAD	= International Fund for Agricultural Development.
LDCs	= Less Developed countries.
MEDaC	= Ministry of Economic Development and Corporation.
MOA	= Ministry of Agriculture.
MPP	= Minimum Package Project.
NARSS	= National Agricultural Research Systems.
NFIU	= National Fertilizer and Input Unit.
OLS	= Ordinary Least Square.
PADEP	= Peasant Agricultural Development Program.
PADETES	= Participatory Demonstration and Training Extension System.
SAP	= Structural Adjustment Program.
SG-2000	= Sasakawa- Global 2000.
SIDA	= Swedish International Development Authority.
SSA	= Sub Saharan African.
TGE	= Transitional Government of Ethiopia.
TLU	= Tropical Livestock Unit.
USAID	= United States Agency for International Development.
VCR	= Value Cost Ratio.
WADU	= Wellamo Agricultural Development Unit.

Abstract

This study examines the productivity and profitability of teff and wheat technologies in selected villages of Ethiopia, namely Sribana-Godeti, Eteya, Shashemene and Yetmen using Cobb-Dauglass production function model. The paper indicated improved seed varieties, recommended rate of DAP and Urea, farming management (practices) and environmental factors have a significant positive impact on productivity. In addition, land under new extension system resulted in better yield responses than farmers' practices.

The study showed that most farmers did not use improved seed varieties and recommended rate of Urea and DAP which enhance productivity and profitability. High costs of improved seeds and fertilizer, lack of money for down payment, lack of credit and loans etc were reasoned out as the major one.

The paper also established that the existing technology package was profitable if land cost was not considered. If land cost was included most of the farmers earned profit less than the market wage rate except Sirbana-Godeti farmers. Thus, hiring-out labor is more preferable than renting-in for landless farmers. This paper concluded that emphasis should be directed towards the transformation of the agricultural sector through application of more productive technologies.

Agricultural Development Unit (CADU, later called Arssi Regional Development Unit, ARDU). It was established in 1967 through a cooperation agreement between Ethiopian Government and the Swedish International Development Authority (SIDA). The second was the Wellamo Agricultural Development Unit (WADU) that was established in 1970 through World Bank assistance. WADU was followed by the Ada District Development Project (ADDP), which began operation in 1972 and was assisted by United States Agency for International Development (USAID).

However, the experience gained from CADU[1] and to some extent from WADU as early as 1970 proved that the intensive package programs were too costly in terms of manpower and financial resources for large-scale expansion. An alternative strategy, more commensurate with the resources of the nation, had to be designed. This alternative strategy was called the Minimum Package Project (MPP) and was launched in 1971 with technical assistance from SIDA.

The MPP was designed to reach a large number of farmers with few "proven" innovations that have been developed or tested by intensive package projects and/or agricultural research institutes of the nation. The proven innovations essentially consisted of fertilizer, improved varieties of cereals, and the accompanying cultural practices i.e. method and rate of application of fertilizer, sowing rate and sowing dates of the improved varieties of seeds. The approach employed in MPP was supposed to be less costly on per farmer bases than CADD, WADU, or ADDP. But evaluation of the project proved that its objectives was not achieved since the expansion of commercial farming seriously constrained the impact of the projects on smallholders agriculture [Mulat, 1989; Dejene 1999].

[1] Report of Chilallo Agricultural Development Unit (CADU) 1969

The Military government (Derg), which took power in 1974, introduced radical political and economic changes guided by socialist ideology. After the radical land reform in 1975, agricultural sector policies of the new government were characterized by nationalization of all private and commercial farms into state farms. Collectivization of peasants into producers and service cooperatives was taken as the development strategy. Private investment in the agricultural sector was forbidden. In order to discourage private sector, government employed polices of villagization and control of all marketing of agricultural inputs such as chemical fertilizer and improved seeds. Furthermore, the movement of all agricultural output from one country to another was restricted and quota was imposed to deliver foodgrain to government parastatal, Agricultural Marketing Corporation (AMC) at low price [MEDaC, 1999].

The model farmer approach employed by the agricultural development projects was rejected on the ground that it led to a situation where a few farmers became rich and the vast majorities were left behind. Equity implications were considered as the main drawback of the projects. The Military government attempted to reorganize the projects in line with its socialist policy of discouraging income disparity [Mulat, 1999a].

A new project under the name of Peasant Agricultural Development Program (PADEP) was launched in the early 1980s with the aim of increasing food production and promoting service and producer cooperatives. The World Bank, the International Fund for Agricultural Development (IFAD), SIDA and the Italian government were expected to provide the financial and technical support for the project. However, the full operation of PADEP was delayed by disagreement between the donors and the government over the role of small farmers and state intervention in grain markets [Mulat, 1999b].

In general, as a result of the restrictive policies, civil war and drought the bright feature of smallholder agricultural development that was initiated in the 1960s was dimmed under the derg period.

Following overthrew of the Military government (Derg) in May 1991, the Transitional Government of Ethiopia (TGE) introduced a new economic policy. The major objective of TGE was to replace the previous regime's centrally planned economic system with market-oriented system. The implementation of the system depended on the principles of decentralization, autonomy, competition, efficiency and profit maximization [MEDaC, 1999]. The government implemented these policies to attain fast and broad-based economic development. An economic reform program was also initiated, which took the form of Structural Adjustment Program (SAP) under the auspices of the World Bank and IMF [Mulat, 1999a].

In order to improve agricultural productivity, the Federal Democratic Republic of Ethiopia (FDRE) initiated a broad based Agricultural Development- Led Industrialization (ADLI) strategy in the early 1990s. The strategy concentrated on accelerating growth through focusing on the supply of fertilizer, improved seeds and other inputs. It viewed agriculture as the engine of growth, on account of its potentially superior growth linkages, surplus generation, market creation, and provision of raw materials for industry and foreign exchange [MEDaC, 1999].

Low level of improved technology utilization is one of the main causes of low agricultural productivity in Ethiopia. For example, out of the total cultivated crop area in 1997/98 meher season of private peasant holdings, the percentage distribution and application of fertilizer (both natural and commercial), pesticide and improved seeds was only 34.47, 9.23, and 1.95 per cent, respectively. The area under irrigation is also less than one per cent. The largest portion of fertilizer, pesticide and improved seed was applied on wheat (60.56, 31.26 and 5.58%, respectively), followed by teff (47.9, 17.71 and 1.73, respectively) (Table 1).

The bulk of the financial resources finance technology adoption and dissemination has been from donors. According to Mulat (1999a), donors financed the agricultural development projects implemented under the Imperial and the Military governments. There was a clear lack of government commitment to technological transformation of smallholder agriculture. Furthermore, the absence of a core-operating budget has meant that project activities are terminated once the project period is over or donors refuse to extend their support.

Agricultural development strategies and policies also lacked continuity and people's participation. Development projects and priorities were changed or terminated and new ones were initiated without much effort to draw lessons from previous experiences. Several projects have come and gone within a span of less than one generation. The result has been farmers' lack of confidence in new schemes that purport to assist them. Lack of people's participation in the formulation and implementation of development projects compounded the problem.

TABLE 1: ESTIMATE OF IMPROVED SEED, IRRIGATION, PESTICIDE AND FERTILIZER-APPLIED AREA AND THEIR PERCENTAGE DISTRIBUTION BY CROP FOR MEHER SEASON OF PRIVATE PEASANT HOLDINGS 1997/98 (1990 E.C).

Type of Crop	Total crop	Improve seed applied		Irrigation		Pesticide applied		Fertilizer applied (Natural and Commercial)	
	Area	Area	%	Area	%	Area	%	Area	%
Cereals	5599.94	134.9	2.41	34.14	0.61	671.88	12.00	2199.9	39.28
Teff	1747.13	30.24	1.73	11.54	0.66	309.36	17.71	837.13	47.91
Barely	681.84	0.99	0.15	4.23	0.62	65.65	9.63	288.8	42.36
Wheat	787.61	43.93	5.58	2.54	0.32	246.18	31.26	477	60.56
Maize	1099.87	57.44	5.22	12.14	1.10	14.13	1.28	368.17	33.47
Sorghum	954.38	2.3	0.24	3.69	0.39	29.78	3.12	99.33	10.41
Millet	289.73	**	**	**		1.93	0.67	116.42	40.18
Oats	39.38	**	**	**		**	**	13.05	33.14
Pulses	837.37	0.5	0.06	1.92	0.23	15.81	1.89	116.75	13.94
Oilseeds	380.5	**	**	**		4.59	1.21	32.29	8.49
Others	190.96	**	**	7.35	3.85	3.89	2.04	58.82	30.80
All temporary	7008.74	137.59	1.96	44.78	0.64	696.17	9.93	2407.76	34.35
Total permanent	558.22	11.97	2.14	18.86	3.38	2.59	0.46	200.79	35.97
All crops	7566.99	147.37	1.95	62.27	0.82	698.76	9.23	2608.55	34.47

Note: ** missing observations

Source: CSA, Agricultural Sample Survey 1997/98 (1990 E.C)

1.2. Statement of problem

Agricultural productivity is very low in Ethiopian. Development efforts made under CADU, ARDU, WADU, ADDP, MPP or SG-2000 seem to have failed to bring any significant change (countrywide) in agricultural productivity. Cereals yield, for instance, increased by only 0.3% per annum between 1980 and 1997 and yields remained unchanged in the cases of pulses and oilseeds. What is more worrying is the fact that yields have not shown any significant improvement since 1994, in spite of the sharp increase in fertilizer and other inputs (Mulat, 1999b).

The stagnation of agricultural productivity in Ethiopia can be due to two main factors: First, farmers (due to scarcity of land) cultivate the land continuously. The natural fertility of soil is declining due to continuous cultivation. The fertility needs to be maintained by replacing the nutrients, which are taken out of the soil. The existing level of improved technologies utilization only replace the amount of nutrients taken away with the harvested yield rather than improving productivity. Thus, the yield trends of have become almost constant.

Second, farmers cultivate marginal land due to shortage of fertile land and other alternatives to secure their lives. The yield obtained from marginal land is very small and it doesn't even cover farming cost, since such type of land has almost lost its nutrient contents suitable for plant growth. Even if there is a higher yield in some areas, the aggregate total productivity of the country has stagnated.

Different studies suggest the possibility of increasing agricultural productivity in Ethiopia by promoting the use of proper technology packages. But the question is, is there full technology package (a package which consists of high yielding variety of improved seed (HYV), chemical fertilizer (DAP and urea), herbicide, pesticides, farming management practices etc together) at the farm levels? In the absence of a complete package, do farmers get adequate profit from existing selected technologies? In light of these, this study tries to investigate the productivity and profitability of different types of improved agricultural technologies of small farmers.

1.3. Objectives of the study

There is an increasing recognition that the potential for increasing agricultural output and improving the life of the rural population lies in raising the productivity of small farmers. However, this strategy can't be effective in the absence of new or improved agricultural technologies [Schultz T.W, 1964 Patil, and Dayanatha, 1978]. The introduction of new technologies such as fertilizer, high yielding varieties (HYV), herbicides and improved farm management practices is necessary to increase productivity. Thus the main objective of this study is to analyze productivity and profitability of improved technologies of wheat and teff. Specifically, the study has the following objectives:

- Identify and evaluate empirically the relative contribution of improved technologies to yield.

- Assess the profitability of improved technologies of wheat and teff (improved seed varieties, chemical fertilizers, improved farm implements, herbicides packages etc).

- Propose some strategies and polices that would contribute to the realization of a sound agricultural development policy.

1.4. Significance of the study

There is a general believe among political leaders and agricultural experts that farmers can increase their productivity and profitability with the use of appropriate inputs such as improved seeds, fertilizer and herbicide; farming practice (management) such as frequent plowing and weeding, timely operation of farming activities (land preparation, planting, weeding, harvesting etc,).

In a country like Ethiopia, where agricultural intensification is given top priority to the country's development strategy, the analysis of improved technologies on productivity and profitability are quite relevant and appropriate to bring about rapid and sustainable agricultural development.

In Ethiopia, a number of empirical studies have identified the factors influencing technology adoption. A few studies have suggested that farmers who adopt new technologies have higher yield than non-adopters. The impact of different technologies on productivity and profitability has rarely been studied. Hence, there is a crucial need for policy makers to study the impact of these technologies not only on productivity but also on profitability. Furthermore, following the devaluation of Ethiopian currency, Birr and removal of fertilizer subsidy, the cost of improved technologies has been increasing. As a result, productivity of improved technology may not necessary mean profitability of the technology.

Generally by analyzing the impact of improved technologies on productivity and profitability of teff and wheat, the study would provide evidence to policy makers that would be useful in their decision-making process. Additionally, this study is expected to have a valuable contribution to the existing literature in the field and act as a stimulus for further researches.

II. LITERATURE REVIEW

In this section an attempt will be made to review both theoretical as well as empirical literature. The first sub-section discusses the theoretical background and some empirical evidence will be followed in the second sub-section.

2.1. Theoretical background

The adoption of new technologies and production approaches in farming activities is becoming crucial for countries in order to meet the challenges of rapidly growing populations and decreasing productive lands. At the beginning of the 20th century, growth in world agricultural output was obtained mainly by increasing the total area of cultivated land; East Asia, Middle East, and Western Europe remained the only exceptions since they had very limited land to spare for agricultural expansion. But as the low cost land conversion possibilities are continually exhausted, almost all increases in world agricultural production will have to come from higher output per hectare [Jude et al. 1986; Rutta 1987]. In light of this requisite a shift from a resource-based to a more science-based system of agriculture, the agricultural research sector (technology invention/adoption), will have to play an increasingly important role in improving agricultural productivity [Dinal L.Umali, 1995a].

The increased dependence on science-based agriculture, bolstered by the rapid agricultural technological advances in the last half century, has placed greater importance on the rapid and efficient transfer of advanced knowledge to farmers. Farmers' decisions regarding technology choice and resource allocations are based on their stock of knowledge. By and large, farmers and/or society in general will benefit from farmers' access to land adoption of improved information (either pure or embodied in new technologies) because it is likely to result in increased productivity and possibly other benefits, such as improved nutrition [World Bank, 1995].

This long-term process of shifting from a resource-based to a technology-based system of agriculture underlines the demand and supply of agricultural information. Agricultural information transmitted to and from farmers can be classified into pure agricultural information and agricultural information inherently tied to new physical inventions. Pure agricultural information refers to any information that can be used without the acquisition of a specific physical technology. This includes cultural and production techniques, farm management, marketing and processing information and community development. Agricultural inventions or technologies generally come in the form of inputs to farm production, technologies facilitating farm management, marketing and processing equipment etc, [Umali et. al., 1995b].

In general growth in food production must be achieved through increased yield from the same land already under cultivation. Moreover, these yield increase must be achieved through the application of already-available technologies. Adoption of available agricultural technologies on lands that are more suitable for cultivation will not only lead to economic development, but also will solve the serious environmental problems that result from cultivating unsuitable lands [Dowswell, 1994].

Intensification of agriculture as well implies both continuous rise in productivity at a given point in time and over time through efficient allocation of resources. Various allocative mechanisms such as prices, taxes, and other fiscal controls, should be considered to achieve the intensification objective and to tackle the root causes of the problem. Intensification of agriculture driven by such forces as the capacity of generating science-based practices and techniques to users and farmers, training the farming community to increase the adaptive/absorptive capacity of the technology, devising and creating a conducive environment for community participation and decision-making in areas that affect their livelihood [Pearce, 1988].

In Sub-Saharan Africa (SSA), the growth in agricultural production in the past was achieved by expanding the amount of land cultivated. Today there is little scope for increasing the area under cultivation. Future increases in agricultural production could be achieved by increasing the productivity of land and labor. This requires a generation of effective and efficient agricultural technologies. The governments of the SSA should also adopt appropriate policies, so that farmers apply these technologies to increase productivity [Venkatesan V. et. al, 1998].

The adoption and diffusion of improved technologies in agriculture has been a major area of research to development economists and economic planners in many less developed countries (LDCs) since the majority of the population in these countries depend on subsistence agriculture. There is an argument among researchers in these countries that the introduction of improved agricultural techniques or technologies (improved seeds, chemical fertilizers, herbicides, improved farm implements and cultural practices) increases the production and income of subsistence farmers. However, the introduction of these improved technologies in many of the LDCs has only been partially successful as measured by observed rate of adoption [Gershon et. al., 1981].

It is widely thought that important lessons can be drawn for Africa from the Green Revolution technology, which significantly increase production in many Asia and Latin American countries over the last three or four decades. It gave rise to a dramatic increase in yields of some crops such as wheat and rice in part of Mexico, the Philippines, India, Pakistan and Thailand. The Green revolution has increased the overall economic growth rates of these countries, moderated the rate of inflation, reduced imports of foods and thereby eased balance of payment problems, and raised supplies and stocks of food staples [Griffin 1989].

Modern science and technology that have brought a green revolution in both food and export commodities in Asia is not the case in Africa, because African farmers have shown little interest in high-yielding varieties, such as those developed in Asia in the context of green revolution. Adoption of high yielding varieties is not typical to Africa because those varieties generally perform well only under a controlled environment where there is no shortage of water (using irrigation) and where chemical inputs can be widely used. In general, there is little irrigation available and inputs are scarce in Africa. So the problem is not so much of developing high-yielding varieties that need a lot of care, but of growing varieties that can adapt to a difficult environment and eventually develop resistance to several diseases, such varieties will give moderate yield despite nutrient deficiencies [Antonie, 1992].

Some scientist or researchers claim that yields in Africa could have been many times the present figures, if only farmers have applied available technologies. The low average use of fertilizer (estimated rate 9 to 11 kilograms per hectare) and of irrigation (estimated as 4 to 6 percent of cropped area) further suggest the high potential and long-term technical capacity for expanding production through seed-fertilizer-irrigations strategies. These arguments are often used to support the view that further investment in National Agricultural Research Systems (NARSs) is futile. However, attempts to introduce new technology into African agriculture in the past thirty years have often been disappointing, because there were frequently difficult to be applicable for the subsistence farmers in these countries [World Bank, 1989]. Farmers lacked the capital and water resources to make use of the available technologies. Moreover, government price and marketing policies often made the technologies economically unviable [Venkatesan. V et. al., 1998].

Technologies are certainly available to increase productivity of farmers. But economic and financial factors make this technology inapplicable to most smallholders in rural areas. While many do consider tractors as an available but inapplicable option for small-scale African subsistence farmers, what has been less appreciated is the difficult situation that the farmers has faced to apply and adopt apparently simpler technologies. Timely cultivation, planting and weeding can have a striking impact on yields, and farmers know about them, but for many farm families where males are working in the cities and which face severe labor constraints at critical points in the crop cycle, that technology is often not practicable. Hence, the need for research to evolve technologies relevant for each of farmers [Carr, 1989].

The real expenditures on agricultural research have increased nearly five folds between 1959 and 1980 [Evenson, 1985]. There is no doubt that increased agricultural research in developing countries is now paying off. There was a wide gap of grain yield between the developed and the developing countries between 1952-56 and 1969-70. However, since the 1970s the gap has been narrowed from 52% to 36%. During the late 1930s grain yield was similar all over the world. The great achievements of higher yield and output in developed countries was to a considerable degree due to the benefits they could obtain from biological and chemical resource applied to agriculture [D. Gale Johnson, 1988].

But there are large areas of rain-fed agriculture that have benefited little from expenditures on agricultural research. This is particularly true of the relatively arid areas found in Africa and Asia. While research efforts seeking solutions to the productivity problems of arid areas have been increased, the positive consequences have been limited. Given the adverse effects of policies in many developing countries, one can't be certain whether absence of improved technology could have been the primary factor (reason) for stagnation and/or declining yields in SSA. Nevertheless, we do know that even though there are some promising research developments, there have been no breakthroughs comparable to the seeds and production technologies associated with hybrid corn, rice and wheat produced in humid areas or under irrigation. Research is needed for the profitable development of agriculture in the humid tropics as well as in the dry areas. As population grows, research is needed to develop self-sustaining cropping systems that do not depend upon long fallow to maintain level of yields [D. Gale Johnson, 1988].

Modern technology is one among the five factors[2] necessary to set agricultural production moving (the dynamic of technical change in agriculture). Emphasis should be given on the need

[2] Five factors are: market, new technology, and local availability of supplies, adequate incentives and transportation.

for a package of policies and programs to get agriculture moving. But, modern technology alone is not enough to get agriculture moving; there are institutional, infrastructural and cultural factors that must be changed in the process of transformation [Morsher, 1996].

2.2. Some empirical evidences of Ethiopia

Agricultural Development Department, ADD and National Fertilizer Input Unit, NFIU (1986-89) reported that agricultural research institutions had done various studies that gave clues to the effect of intensification in Ethiopia. For instance, with improved seeds, commercial fertilizer and improved soil and water management, an increase in crop production of at least 100 percent in dry land has been achieved. The profit earned across the country as a result of fertilizer application was also high. The highest profit was earned for wheat and teff (263 and 186 Birr, respectively). The increase in output was higher at higher and more reliable rainfall regions.

Abate (1995) conducted analysis on on-farm improved production of Durum wheat in three districts of Ethiopia namely Ada, Akaki and Enewari. He found that the recommended varieties (Boohai) on on-farm trials under various agro-ecological situations yielded more than respective local varieties. According to his findings, increase in yield of new varieties over the local was 63.22, 54.59 and 41.29 percent in Ada, Akaki and Enewari districts, respectively. The marginal rate of return of improved varieties over local was also calculated and found to be 9.73, 8.07 and 5.67 (Birr/ha) in Ada, Akaki and Enewari districts, respectively.

Study on Fertilizer Procurement, Distribution and Consumption in Ethiopia by Mulat (1995) suggested that the value cost ratio (VCR) for teff in Gojjam and Arssi was greater than 2.5. Hence applying fertilizer on teff provided sufficient profit in these areas.

Teklu (1995) carried out analysis on on-farm verification of an improved durum wheat production package in Ada and Akaki areas of Ethiopia. To address the profitability of the technology, he computed partial budget analysis using labor, fertilizer and yield data for variety versus management combinations. The result of the economic analysis revealed that the total costs that vary ranged from 587.38 Birr/ha for the improved variety with local management practices to 696.38 Birr/ha for the improved production package. The total cost that vary for the local seed (609.88 Birr/ha) happened to be greater than the total costs that vary for the improved variety with local package. This was mainly attributed to the higher work days in weeding the local seed as compared to that of improved with local package.

Mohammed et. al., (1995) also conducted on farm verification of advanced breed wheat lines in Arsi zones. In his findings, the variation among local and improved varieties was found almost in all sites. Accordingly, significant differences among treatments, sites and interactions were observed in Asasa and Bokoji but not in Arsi-robe. In Etheya zone, significant differences were detected between sites and management. According to him, the absence of grain yield differences among varieties in the zone may be due to the use of a high yield potential variety and to the low incidence to stripe rust of that year.

They also found that site mean yields ranged from 1574 kg/ha in Arsi- Robe to 4043 kg/ha in Bokoji. Among zones the highest yield (2340 kg/ha) was recorded in Etheya/Gonde and the lowest (1937 kg/ha) was in Aris-Robe. This showed the high variability of yield from location to location and from site to site within locations. He continued, over zones, under both management levels, HAR 604 gave the highest yield though the incremental yield over the other varieties was marginal. However, the magnitude of yield differences among varieties was higher under farmers' management. The incremental yield of HAR 604 relative to HAR 1685 and the local varieties taken together under farmers' management condition was 435 kg/ha and 362 kg/ha, respectively.

The battle to keep up food supplies with fast growing population in Ethiopia will continue to be a major task. To feed the ever-growing population, small-scale farmers should be equipped with science-based modern agricultural technologies. For instance, the use of chemical fertilizers must be expanded from present low level, combined with higher yielding varieties and improved crop management practices. There are formidable obstacles in the way of developing adequate systems for delivering improved seeds, fertilizers and crop protection chemicals; and for providing vital services such as credit, storage and marketing. Agricultural production in Ethiopia will only increase if all the necessary basic components for development are properly packaged [Takele, 1996].

He stated that SG 2000 demonstrated improved wheat production technologies on both Vertisols and non Vertisols. On Vertisols wheat production is marginally more profitable under traditional practice (MRR=100%) but can also be quite profitable under improved management (MRR = 285%). The existing technology has the potential to increase productivity even above the 30 qt/ha average, if properly implemented. The highest yield SG 2000 participating farmers attained on Vestisols is 45 q/ha. He further noticed that wheat production in Ethiopia is mainly practiced in Nitosols and loam and sandy loam soils. Average yield was 12.9 qt/ha. During 1994 some 451 wheat Extension Management Training Plots (EMTPs), sponsored by SG 2000, were planted on non-Vertisols soils in many of the most important wheat-growing regions in the country. The average yield of the EMTP farmers was 115% above the traditional average.

According to Takele (1996), a partial budget analysis for wheat productions had shown that, with improved management and use of inputs such as improved seeds, moderate amounts of fertilizers, and herbicides for both broad-leaved weeds and grasses, wheat production was quite profitable (MRR=315%). In his description of the effectiveness of SG 2000, he stated that even teff EMTPs, from northern and northwestern parts of the country, seem to show very spectacular results, some exceeded the 30qt/ha level. He also indicated that yields from 0.5 ha of teff and wheat demonstration plots, sponsored by the government have increased by 240 and 300 percent respectively. The average yield per hectare for teff and wheat had also gone up to 12.6 and 29.0 respectively.

Gavaian and Gemechu (1996) investigated the profitability of different wheat production systems in Tiyo area, Arssi zone by comparing farmers' practices in the 1994 crop season with on-farm demonstrations led by both Sasakawa-Global 2000 and Kulumsa Research Center of the Institute of Agricultural Research. According to their findings, yields on demonstration plots were higher than those on unsupervised farmers' plots. While farmers do plant improved wheat varieties, they tend to recycle seeds retained from their own stock rather than purchasing new seed each year. Additionally, farmers use less fertilizer and herbicides than either MoA extension agents or researchers recommendations.

The partial budget analysis was computed for both farmers' practice (oxen-plowed plots) and demonstration plots. Farmers' practice was categorized into average, low, medium and high technology[3] farmers. The average returns to land and labor from low, medium and superior technology (in Birr/ha and Birr/day respectively) was 1673 and 29, 1225 and 21, 2392 and 40, 3182 and 47, respectively. According to them a breakdown of farmers practices by the amount of purchased input showed that the top 4% of the farmers surveyed were able to produce as much as more grain on their plots as on the demonstration plots with comparable or greater profits.

The other categories were SG-1, SG-2, KRC-1 and KRC-2 demonstration plots[4]. The average land and labor returns from the demonstration plots were (in Birr/ha and Birr/day, respectively) 2654 and 40, 2469 and 38, 3457 and 46, and 2656 and 39, respectively. On the whole, they concluded, the demonstration plots offer yields and profits greater than farmers practices in the region area, even after adjusting for capital costs and possible price fluctuations.

Julie H. et. al., (1999) evaluated the productivity and profitability of new technologies based on the survey data by plot types[5]. The survey included: 226 of program plots who participated in the program during their study; 107 control plots where participants used their usual or "traditional" practices; and 157 plots of program graduates used either improved or traditional

[3] (1) Average refers to any types of farmers' on unsupervised wheat plots; (2) Low technology refers to use of recycled seed and fertilizer on unsupervised wheat plots; (3) medium technology refers to use of recycled seed, fertilizer and herbicides on unsupervised wheat plots; and (4) high technology refers to use of improved seed (i.e. from government), fertilizer and herbicide on unsupervised wheat plots.

[4] -SG-1: Sasakawa -Global 2000 demonstration plots with 150Kg/ha of improved k6295-4a seed, 100Kg/ha DAP, 100Kg/ha Urea, 1l/ha 2, 4 -d herbicide, 1l/ha Sarane M herbicide. Budget based on mean unadjusted yields of 2950 Kg/ha.
-KRC-1: Kulumsa Research Center demonstration plots with 175Kg/ha HAR 1685 seedm159 KG/ha DAP, 1l/ha 2, 4-D herbicide, and 1l/ha puma super herbicide. Budget based on yields that have been adjusted downward 11% to discount for the 1995 climate effect.
-KRC -2: same as KCR - 1 except that yields have been adjusted downward 26% to discount climatic, managerial and harvesting effects.
-SG-2: same as SG-1, except those yields have been adjusted downward 5% to discount the managerial effect.

[5] Basically they deal with three plot types, namely MOA/SG/NEP program, Traditional and graduate plots.

practices from two maize growing districts (Jimma and W. Shoa) and one teff growing district (E. Shoa). They draw that both teff and maize were productive and profitable under any of the technologies considered.

Accordingly, the use of improved technology allowed farmers to achieve yields that were substantially higher than national and regional averages for both maize[6] and teff. In the case of teff, for instance, although the yields obtained for all plots are similar-about 1.4 - 1.5 tons/ha or 50 - 55 higher than national and regional average yields of 0.9 ton/ha and 1 ton/ha, respectively [FEDRE 1977]. They reasoned out that the lack of a significant difference across plot types was due in large part to the use of both improved seed and fertilizer on both traditional and graduate plots[7]. Further, they confirmed that yields for plots where farmers used high-input technologies were much greater than yields for plots used low-input technologies.

They found the use of improved technology was also very profitable for both maize and teff farmers' even if output price of the time decline by 25% or 50%. Net income/ha ranged from 110 - 410 Ebr/day for farmers using improved technology. Returns to family and mutual labor ranged from 1.6 to 4.48 Ebr/day for improved technology users, far exceeding average daily wage rates (3 - 5 Ebr/day) in all cases.

Mulat (1999b) conducted a study on profitability of wheat based on a review of previous works on profitability of agricultural technologies, interviews and group discussions held with

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researchers at Kulumsa, Bako, Debre Zeit and Holleta research centers, CIMMYT, extension agents, farmers around the research centers, Ministry of Agriculture (MoA) etc. What was revealed by the study was that, although technology and farm management practice influenced the response to wheat, a partial budget analysis showed a new seed variety of wheat (HAR 1685) was profitable under the recommended management. The return to land was 2,760.63 Birr per hectare and the return to labor was 47.83 Birr per labor day. Under farmer's management, HAR 1685 gave a return of 2,172.15 per hectare (down 21.3) and 43.45 Birr per manday (down 9.2). The marginal cost and returns due to the recommended management (relative to farmers' management) were 1,317.60 and 729.12 Birr, respectively. Hence, the marginal rate of return was 80.7%, lower than the commonly recommended rate of 100%.

III. METHODOLOGY AND SOURCE OF DATA

The basic source of data for this study is the fifth round of the 1999/2000 Ethiopian Rural Household Survey conducted by Economics Department of Addis Ababa University in Collaboration with the United States Agency for International Development (USAID).

The survey was conducted in four regional states namely Tigray, Amhara, Oromia and SNNP. The total number of sample households covered by the survey was 1861 from 21 peasant Associations located in 18 sites[8]. The issues addressed by the survey include household demographic features, asset ownership, land and other input uses, crop production and marketing, education, livestock ownership, land use arrangements and other socio-economic aspects of rural households.

This study examines the impact of technological inputs on productivity and profitability of teff and wheat. To this end, plots in Sirbana-Godeti and Yetmen areas were selected for teff and plots in Eteya and Shashemene for wheat. Teff and wheat were chosen mainly because they are one of the major staple foods of the country. In selecting the areas (sites), two major criteria were taken into consideration. The first and the major criteria was the existence of improved technologies in the sites. Sirbana-Godeti (teff) and Eteya (wheat) were selected based on these criteria. The second criterion was the share of plots under extension and the number of plots allocated for the production of those crops. Accordingly, the share of plots under extension in Shashemene (wheat) and the number of plots allocated for teff production in Yetmen were higher

[8] The areas include (1) Haressaw and Geblen from Tigray regional state; (2) Sirbana-Godeti, Adele Tique, Koro Degage, Shashemene, Eteya, Bako Tibe and Somodo from Oromia regional state (3), Ankober, Debrebrehan, Yetmen and Shumsha_Lalibela from Amhara regional state and (4) Indibir, Azedebos, Adado- Dilla, Gara Godo-Araka and Domma from SNNP regional state.

than other sites. Hence both of them were taken for the analysis to make comparison against technology adopters. All in all, a total of 322 households (61, 95, 97 and 69 from Yetmen, Sirbana-Godeti, Shashemene and Eteya, respectively) were taken.

In the course of managing the data, some erroneous figures that might have resulted from recording interviews, misunderstanding of measurements and/or data entries were observed and edited. Furthermore, some extremely low and high values of inputs (in kg/ha) and yield (output per ha) were also identified. Thus, inputs of plots with such incredible figures were replaced with the peasant associations' modes (highly frequented values) of inputs. In addition, 53 plots that have not employed any input and 7 plots that have not used any chemical fertilizer were found. Finally, after data has been cleared and some minor adjustments were made, some 391 plots of teff (54%) and 341 plots of wheat (46%), (a total of 732 plots) were taken from the four areas.

3.1. Model specification

3.1.1. Productivity of improved technologies

Technology can be broadly defined as a combination of (1) technological factors such as high yielding varieties of seed (HYV), chemical fertilizers (DAP and Urea), herbicides, insecticides, fungicides etc; (2) environmental (exogenous) factors such as quality and topography of the land, total distribution of rainfall, crop damage due to various reasons such as plant diseases, frost, flood, bird etc., and (3) farming practices (management) such as crop rotation, number of plowing and weeding, time of land preparation, planting, weeding etc.

The magnitude of improvement in productivity for those technologies of teff and wheat were examined through production function of the following specification:

$$Y = F(X, E) \ldots\ldots(1)$$

Where: Y = Yield response of technologies of teff and wheat.
E= is vector inputs such as sex, age and education level of household head.
X= is a vector of variable inputs (different combinations of technological and environmental factors and farming practices).

Depending on the research question, frontier or non- frontier (direct methods of estimating) production function can be specified. Since the main focus of the research is estimating the coefficients of those physical inputs and technology combinations, non-frontier techniques were employed.

For direct estimation of production function the translog production function model is more flexible than restricted Cobb-Douglass (C-D) production function model [Green, 1980:48]. However, this study is limited to use the restricted C-D production function model due to high multicollinearity problem when translog production function model is applied.

We may express the C-D production function as:

$$Yi = \pi (X_{ij}^{\beta j} E_{ij}^{\delta j}) e^{\alpha+\varepsilon i} \ldots\ldots (2)$$

Where: Y_i is yield response of the i^{th} plots, X_{ij} is the use of i^{th} plots of the j^{th} technological inputs, E_{ij} is the use of the i^{th} plots of the j^{th} physical inputs and β_j and δ_j are elasticity of Y_i with respect of X_j and E_j, respectively.

To measure the work effect of each physical input and technological input, Cobb-Douglass (C-D) production function may be specified in semi-log linear forms as follows.

$$Ln\Sigma Y_i = \alpha + \Sigma\Sigma\beta_i \ln X_{ij} + \Sigma\Sigma\delta_j E_{ij} + \varepsilon i \ldots\ldots (3)$$

Equation (3) can be rewritten as

$$LnY_i = \alpha + \beta_1 Lnseed_i + \beta_2 LnDAP_i + \beta_3 Lnurea_i + \beta_4 Lnherb_i + \beta_5 techdummy1_i + \beta_6 techdummy2_i + \beta_7 techdummy3_i + \beta_8 techdummy4_i + \beta_9 techdummy5_i + \beta_{10} techdummy6_i + \beta_{11} techdummy7_i + \beta_{12} envirodummy1_i + \beta_{13} envirodummy2_i + \delta_1 hhage_i + \delta_2 doxen_i + \delta_3 Offarm_i + \delta_4 lnhhfsize_i + \delta_6 hhedu_i + \varepsilon_i \quad \ldots\ldots (4)$$

Where α *= constant term*

LnY_i = the natural logarithm of yield responses of the i^{th} plots (in kg/ha).

$Lnseed_i$ = the natural logarithm of seed inputs (improved and/ or local) of the i^{th} plots (in kg/ha).

$Lndap_i$ = the natural logarithm of DAP chemical fertilizer inputs of the i^{th} plots (in kg/ha).

Lnurea= the natural logarithm of Urea chemical fertilizer inputs of the i^{th} plots (in kg/ha).

Lnherb = the natural logarithm of herbicide application inputs of i^{th} plots in (kg/ha).

Techdummy1= 1 if farmers used improved seeds for the i^{th} plots, 0 otherwise

Techdummy2= 1 if farmers used >=100 kg/ha of DAP & >=50 kg/ha of urea for i^{th} plots, 0 otherwise

Techdummy3= 1 if farmers plough the i^{th} plots >= 4 times, 0 otherwise

Techdummy4= 1 if number of weeding for the i^{th} plots is twice, 0 otherwise

Techdummy5= 1 if farmers reported time for land preparation, weeding, harvesting, threshing etc at normal time for the i^{th} plots, 0 otherwise.

Techdummy6= 1 if farmers were planted legumes plants in the i^{th} plots in the previous three years (at least in one of the years from (1996-1998), 0 otherwise.

Techdummy7= 1 if the land is under extension, 0 otherwise.

Envirodummy1= 1 if the land quality is lem for the i^{th} plots, 0 otherwise.

Envirodummy2= 1 if farmers reported crop damage of the i^{th} plots due to either one of the following: insect, bird, livestock, plant disease, etc.

LnhHhage = natural logarithm of age of household head.

doxen = number of oxen owned by the household : 1 if he has more than 1 oxen, 0 otherwise.

Offarm = 1 if the household head participated in off-farm activities, 0 otherwise

Lnhhfsize = the natural logarithm of household family size.

Hhedu = education level of the household head.

ε_i = *random terms*

The marginal productivity of a factor is one of the most crucial concepts in the theory of production. It represents the changes in output that results from a (small) change in any one input, when all other inputs are held constant. This can be expressed by the partial derivative of output with respect to input, which is represented as follow:

$$\partial Y/\partial X_i \text{ and } \partial Y/\partial E_i \quad \text{.........} \quad (4)$$

3.1.2. Estimation technique

The SPSS econometric package of Ordinary Least Square (OLS) estimation technique was employed to estimate the model. The OLS estimation procedure has a number of desirable statistical properties.

(a) The OLS estimators are expressed solely in terms of the observed (i.e. sample) quantities (inputs kg/ha and yield (output/ha)). Therefore, they can be easily computed.

(b) They are point estimators, that is, given the sample, each estimator will provide only a single (point) value of the relevant population parameter.

3.1.3. Profitability of improved technologies

High yields are not sufficient conditions to persuade farmers to adopt a technology. As is the case of any business, farming with technology application must be basically profitable, or at least more profitable than any other alternative. While standard agricultural budgets omit various hidden costs, such as long queues, bribes, favors, etc, they do provide a simple accounting of the financial costs and benefits to farmers of alternative production strategies [Gavaian and Gemechu, 1995]. Furthermore, in Ethiopia one of the major components of improved technologies, fertilizer, is imported from abroad, which require foreign currency. As the currency of the country is being devalued, the cost of fertilizer is increasing. In contrast, as productivity increases (through use of improved technologies) the prices of the output declines (the principle of demand and supply). This means as cost of input are increasing, output prices are decreasing. This is what makes assessment of profitability of technology very important, in addition to productivity. In the absence of profit from improved technologies, farmers lack incentives to use those technologies in the consecutive years.

Economic profitability that arise from the use of improved technologies in the production of teff and wheat can be captured by the following model[4]:

$$\text{Profit} = (P_y Y - \sum P_{xi} Xi) \quad \text{..........} \quad (5)$$

Where: P_y *= Price of the physical output from the use of the technology*
Y = physical output response of teff and wheat from the use of the technology
P_{xi} *= Price of input Xi applied in the production of Y*
Xi = quantity of input applied in the production of Y

The model shows that the profitability of technology depends on three main factors: (1) the response rate to technology application; (2) the price of output; and (3) the cost or the prices of the technology or inputs applied. The response rate depends on the quality of the technology, the natural growing condition, management factors and availability of complementary inputs. Superior technologies are less risky and generate large economic benefit, and farmers adopt such innovations with enthusiasm. Good land preparation, timely sowing, and effective control against

[4] This model and its intuitive explanation are directly adopted from Mulat (1999b), "Agricultural Technology Variability, Economic Viability and Poverty alleviation in Ethiopia": Presented to the Agricultural Transformation Policy Work shop, Nairobi, Kenya from 27-30 June 1999.

weed and insect are some of the management environment determining output response. The extension system plays a vital role in improving the management capacity of small producers.

A number of variables influence the price paid by farmers for agricultural inputs. The cost of improved seeds, for instance, includes the performance and efficiency of seed multiplication, processing and marketing. A competitive wholesale and retail operations ensure access and reduce the cost of seeds.

IV. RESULTS AND DISCUSSIONS

4.1. Basic characteristics of the households

Some of the basic characteristics of the households in the study sites are depicted in Table 2. The average cultivable land size owned by farmers for which they pay tax (excluding grazing and garden) per household varies from 1ha in Shashemene area to 2 ha in Eteya area. The total own cultivated land (excluding rented-in, sharecropped-in and gifted/lent-in) also varies from one site to another. For instance, the average own land cultivated by each household was 2 ha in Eteya and Sirbana-Godeti, and 1 ha, in Yetmen and Shashemene areas. Rented-in, Sharecropped-in and gifted-in land was reported in all sites except Sirbana-Godeti (Gifted-in land was not reported in Sirbana-Godeti), of which, the highest average rented-in land (1 ha) in Eteya, sharecropped-in (1 ha) in Yetmen and gifted-in (0.31 ha) in Shashemene was reported. No land is left fallow in Yetmen and Sirbana-Godeti areas. In the remaining two sites fallow land reported was also very small.

The average family size of the four sites was about 6 persons with standard deviation of 3. On the average, 7 persons per families were reported in Eteya and Shashemene areas. Sirbana-Godeti and Yetmen had almost equal family size (5 persons per family).

About 22% of all households had women as their head (Table 2). Comparison within each area indicated that 24, 29, 18 and 13 percent of the total household head were female in Yetmen, Shashmene, Sirbana-Godeti and Eteya areas, respectively. Yetmen had the highest number of households with female as their head followed by Shashemene. The illiteracy rate of the household heads was 51% in the study sites. The rate was found to be highest in Sirbana-Godeti

(72%) and relatively lower in Eteya (39%). In Yetmen and Shashemene areas the rate was 41% and 46% respectively.

Cattle ownership on the average was about 5 Tropical Livestock Unit (TLU) per household, lower cattle ownership was reported in Yetmen area (4 TLU per household) and the highest was reported in Eteya (6 TLU per head).

TABLE 2: BASIC CHARACTERISTIC OF THE HOUSEHOLDS

Variables	Yetmen	Debrezeit-Sirbana-Godeti	Eteya	Shashemene	Total Average
Mean age of the head of the household	N=61 47.02 (16.47)	N=95 52.23 (16.60)	N=69 45.19 (14.22)	N=97 47.88 (16.5)	N=322 48.42 (16.10)
Average family size per household	N=61 4.89 (2.25)	N=95 5.46 (6.74)	N=69 6.74 (3.18)	N=97 6.64 (5.89)	N=322 5.98 (2.93)
Land Size (ha)[9]	N=61 1.19 (0.37)	N=88 1.51 (0.59)	N=57 2.12 (0.83)	N=91 0.99 (0.44)	N=297 1.40 (0.71)
▪ Left fallow	-	-	N=4 0.41 (0.19)	N=6 0.16 (0.08)	N=10 0.26 (0.18)
▪ Total own land cultivated	N=46 1.19 (0.35)	N=80 1.50 (0.57)	N=52 2.01 (0.90)	N=76 0.89 (0.40)	N=254 1.37 (0.71)
▪ Land given to other family	N=17 1.04 (0.65)	N=17 0.76 (0.40)	N=17 0.85 (0.53)	N=36 0.60 (0.37)	N=87 0.77 (0.47)
Total land cultivated	N=46 1.73 (0.65)	N=80 1.63 (0.75)	N=63 2.12 (1.14)	N=82 1.06 (0.66)	N=271 1.06 (0.66)
▪ Total own land cultivated	N=46 1.19 (0.35)	N=80 1.50 (0.57)	N=52 2.01 (0.90)	N=76 0.89 (0.40)	N=254 1.37 (0.71)
▪ Rented-in land	N=3 0.46 (0.19)	N=8 1.17 (0.47)	N=23 0.87 (0.45)	N=14 0.50 (0.40)	N=48 0.79 (0.48)
▪ Sharecropped-in land	N=29 0.79 (0.49)	N=3 0.58 (0.38)	N=11 0.60 (0.32)	N=16 0.63 (0.49)	N=59 0.70 (0.46)
▪ Gift/lent-in land	N=1 0.25 (0.00)	-	N=8 0.31 (0.12)	N=7 0.31 (0.12)	N=16 0.29 (0.11)
Average cattle ownership (in TLU)	4.36	5.56	5.61	4.54	5.06
Female-headed households (%)	18.0	24.2	13.0	28.9	22.0
Illiteracy rate (%)	41.0	71.6	39.1	46.4	51.2

Source: Own computation

[9] Own cultivable land (pay taxes)(excluding grazing and garden land.)

4.2. Descriptive analyses of the major factors influencing productivity

The major factors that may influence productivity in the survey sites are discussed below. These factors include technological, environmental and farming practices. The first part deals with farming practices and environmental factors and the second is mainly concerned with technological factors.

4.2.1. Farming practices and Environmental factors

The survey sites, Yetmen, Sirbana-Godeti, Eteya and Shashemene, are found in different agroecological zones. Thus, it would be essential to analyze the major environmental factors and farming practices that have an influence on productivity.

Land qualities for more than 66% of teff and wheat plots were reported as "lem". Only 34, 9, 28 and 26 per cent of them are reported as either "lem-teuf" or "teuf" in Yetmen, Sirbana-Godeti, Shashamene and Eteya, respectively. Similar to land quality, the topography of most of the plots is suitable for farming (plain). Out of the total plots, only 25 % in Shashemene and 8.8 % in Eteya reported as "Dagathema" (Table 3).

Table 3: Land quality and topography (in %).

	Land Quality		Topography of the land	
	Lem	Lem-teuf/Teuf	Medda	Dagathema/Geddel
Yetmen	65.6	34.4	100	0.0
Sirbana-Gedeti	91.0	9.0	99.3	0.7
Shashemene	72.1	27.9	74.3	25.1
Eteya	74.1	25.9	91.2	8.8

Source: Own computation

Farming practices such as timing of land preparation, planting, weeding, harvesting, number of plowing and weeding etc and environmental factors such as rainfall, wind/storm, hail, flooding/water logging are another important variable that may considerably influence yield responses. Accordingly, for more than 90 % of the teff and wheat plots in the survey sites farming practices (management) were performed at normal time (Table 4). However, rainfall started very late and continued for a relatively longer time in Eteya and Shashemene.

Most developed countries apply modern technology for land preparation, harvesting and threshing. In developing countries and particularly in Ethiopia, draft animals and human labor are employed for almost all land preparation, harvesting and threshing. The survey sites also revealed the same results. In Yetmen, Sirbana-Godeti, Eteya and Shashemene land preparation was done by animals and this accounted for 98, 100, 93 and 96 percent of the total plots, respectively. The portion of the plots plowed by tractors was very small (only 6 and 1 per cent of the total plots in Eteya and Shashemene, respectively). Furthermore, human labor for harvesting and animals for transporting to the threshing sites were used in the survey sites. In Yetmen, in addition to harvesting, human labor was also used for transporting to the threshing sites (Table 5).

TABLE 4: TIMING OF FARMING PRACTICES (IN %)

	Normal	Too late	Too early
Yetmen			
Land preparation	95.9	4.1	0.0
Planting	97.5	2.5	0.0
Weeding	100	0.0	0.0
Fertilizer application	97.5	0.8	1.6
Harvesting	94.3	5.7	0.0
Threshing	100	0.0	0.0
Rain stopped	100	0.0	0.0
First kiremt started	100	0.0	0.0
Sirbana-Godeti			
Land preparation	90.5	3.2	6.3
Planting	88.4	7.0	4.6
Weeding	87.0	0.7	12.3
Fertilizer application	85.6	5.6	8.8
Harvesting	89.8	2.1	8.1
Threshing	88.3	5.0	6.7
Rain stopped	34.7	60.0	0.0
First kiremt started	84.0	16.0	5.3
Eteya			
Land preparation	85.2	2.4	12.4
Planting	88.2	7.1	4.7
Weeding	84.5	5.4	10.1
Fertilizer application	94.0	1.8	4.2
Harvesting	91.7	3.2	5.4
Threshing	85.8	6.2	8.0
Rain stopped	36.1	52.8	11.1
First kiremt started	41.7	58.3	0.0
Sheshemene			
Land preparation	100	0.0	0.0
Planting	98.0	2.0	0.0
Weeding	99.2	0.8	0.0
Fertilizer application	98.0	2.0	0.0
Harvesting	98.0	2.2	0.0
Threshing	98.6		1.4
Rain stop	36.1	52.8	11.1
First kiremt started	41.7	58.3	0.0

Source: Own computation

TABLE 5: MAIN METHODS OF LAND PREPARATION, HARVESTING AND TRANSPORT TO THRESHING (IN %)

	Land preparation			Harvesting			Transport to threshing		
	Animals	Hoe	Tractors	Human	Tractors	Both	Human	Animals	Cart
Yetmen	97.5	2.5	0.0	96.7	3.3	0.0	74.6	25.4	0.0
Sirbana-Godeti	100	0.0	0.0	99.3	0.0	0.7	3.5	96.5	0.0
Shashemene	95.9	3.0	1.2	98.2	0.0	1.8	10.8	69.9	19.3
Eteya	92.5	1.4	6.1	88.9	7.6	3.5	2.2	97.8	0.0

Source: Own computation

As mentioned earlier, more than 93 % of the total plots for planting were prepared by animals, particularly oxen. Hence, at least a pair of oxen is essential for individual households. However, about 30, 21, 62 and 26 per cent of individual households in Yetmen, Sirbana-Godeti, Shashemene and Eteya, respectively, reported to have a single ox or none at all (Table 6). This shortage may be covered through mekanajo or gift from relatives.

TABLE 6: NUMBER OF OXEN OWNED (IN %)

Number of oxen	Yetmen	Sirbana-Godeti	Shashemene	Eteya
0	4.5	11.1	19.2	17.9
1	25	9.9	43.6	8.9
2	56.8	42.0	29.5	37.5
3-4	13.6	32.1	7.7	25.0
>4	0.0	4.9	0.0	10.7

Furthermore, as indicated above most of the farming activities such as land preparation, weeding, harvesting, threshing etc, were performed by human labor. Hence, farmers may face labor shortage particularly during the peak periods. According to the report the majority of the households, in all the survey sites did face labor shortage during harvesting (in meher season) but not for land preparation and planting (Table 7). Besides, significant number of individual households has reported labor shortage during all farming activities although their number is less than those who have reported labor shortage during harvesting season. This shortage may not be serious as such since it is compensated by traditional methods of labor arrangement such as "Debo" and "Wenfel". These arrangements were used for the majority of the households who faced labor shortage during harvesting, land preparation, weeding, etc (Table 7).

TABLE 7: RESPONSES REPORTING LABOR SHORTAGE DURING MEHER SEASONS (IN %)

	Planting and land preparation		General cultivation		Harvesting	
	Yes	No	Yes	No	Yes	No
Yetmen	16.3	83.7	6.7	93.3	73.3	26.7
Sirbana-Godeti	7.5	92.5	13.4	86.6	43.6	56.4
Shashemene	28.9	71.1	32.2	67.8	48.3	51.7
Eteya	21.9	78.1	21.9	78.1	57.8	42.2

Source: Own computation

Availability and distribution of rainfall is absolutely essential for crop cultivation and good harvesting. According to the survey results, in Sribana Godeti and Eteya more than 80 percent of the total plots of teff and wheat had adequate rainfall, whereas out of total plots, more than 80 % of teff in Yetmen and 50 % of wheat in Eteya, reported poor rainfall (Table 8).

TABLE 8: TOTAL DISTRIBUTION OF RAINFALL (IN %)

	Rainfall distribution			Total rainfall		
	Excellent	Good	Poor	Excess	Good	Shortage
Yetmen						
Teff	2.5	14.0	81.8	83.5	13.2	3.3
Sirbana-Godeti						
Teff	14.7	66.5	18.8	22.3	67.0	10.7
Wheat	13.6	81.8	4.5	27.3	71.6	1.1
Eteya						
Wheat	0.0	47.6	52.4	1.4	42.9	55.8

Source: Own computation

Wind/storm, hail, frost, flooding/water logging etc are also other factors that may result in significant yield variability. According to the farmers' responses, the plots that faced these problems were very small in Yetmen and Sirbana-Godeti (less than 4% of the total plots). In contrast, nearly 29 % of the wheat plots in Eteya were affected by wind/storm. The wheat plots that faced hail and flooding/water logging problems were also higher in Eteya as compared to plots of Yetmen and Sirbana-Godeti (6.8 and 5.4 % of the total plots in Eteya faced hails and flooding/water logging problems, respectively). The percentage of plots that faced rainfall immediately before harvesting seasons varied from plots to plots. For instance, only 6% of teff plots in Yetmen and more than 50% and 40% of teff and wheat plots in Sirbana-Godeti and Eteya, respectively, faced the problem. In Sirbana-Godeti this problem seems comparatively worst for both teff and wheat plots. The percentage of plots that faced frost was also high. For instance, of the total plots 59 % of teff in Yetmen and 31% of wheat in Eteya were affected by frost (Table 9).

TABLE 9: RESPONSES TO DIFFERENT FACTORS THAT MAY AFFECT YIELDS (IN %)

	Teff		Wheat	
	Yes	No	Yes	No
Yetmen				
Rain near harvest	5.8	94.2		
Wind/ Storm	1.7	98.3		
Hail	0.0	100		
Frost	58.7	41.3		
Flooding/water logging	4.1	65.9		
Sirbana-Godeti				
Rain near harvest	59.4	40.6	52.3	47.7
Wind/ Storm	2.0	98.0	3.4	96.6
Hail	0.0	100	0.0	100.0
Frost	8.6	91.4	15.9	84.1
Flooding/water logging	1.5	98.5	3.4	96.6
Eteya				
Rain near harvest			39.5	60.5
Wind/ Storm			28.6	71.4
Hail			6.8	93.2
Frost			30.6	69.4
Flooding/water logging			5.4	94.6

Source: Own computation

In general, the estimated crop losses due to shortage of rainfall, rain near harvesting seasons, wind/storm, frost and flooding/water logging etc were high. For instance, on average, nearly 4 qt/ha loss of teff was reported in Yetmen, Sirbana-Godeti and Shashemene. Similarly, wheat losses reported on the average amounted for 3 qt/ha in Sirbana-Godeti, 5 qt/ha in Shashemene and 7 qt/ha in Eteya (Table 10). Frost in Yetmen, rainfall before harvesting time in Sribana Godeti and shortage of rainfall in Shashemene were reported as the major causes of crop losses (Table 11). The intensity of crop damage due to plant diseases, insects, weed, bird, wild animals etc, were insignificant for most of the plots (Table 12). Only in Eteya, damage caused by these factors was considerably high (28%). Crop losses in Shashemene were also high although the causes of the damages were not revealed by the survey.

TABLE 10: ESTIMATED CROP LOSSES (IN QT/HA)

	Teff	Wheat
Yetmen	N=24 4.13 (3.21)	
Sirbana Godenti	N=18 3.92 (2.07)	N=2 2.53 (0.19)
Shashemene	N=7 4.22 (5.22)	N=14 4.67 (3.54)
Eteya		N=27 6.51 (5.64)

Note: 1. N = Number of individual household who report crop damage.
2. The figures under parenthesis are standard deviations

Source: Own computation

TABLE11: FIRST MAIN REASONS OF OUTPUT LOSES (IN %)

	Yetemen	Sirbana-Godeti	Eteya
	Teff	Teff and wheat	Wheat
Shortage of rain fall	N=3 (11.5)	N=8 (38.75)	N=11 (42.3)
Rain near harvesting seasons	N=2 (7.7)	N=9 (42.45)	N=3 (11.5)
Wind/storm			N=3 (11.5)
Frost	N=17 (65.4)	N=3 (18.8)	N=3 (11.5)
Flooding/water logging	N=1 (3.8)		
Others (plant diseases, weed, wild animals, bird, livestock etc	N=3 (11.5)		N=6 (28.9)
Total	(100)	(100)	(100)

Note: 1. N= number of households who report crop output losses
2. The figures in the parenthesis indicated the percentage of crop losses due to those specific reasons.

Source: Own computation

TABLE 12: CROP DAMAGE INTENSITY DUE TO DIFFERENT REASONS (IN PERCENT)

	Teff (white & Black and mixed)				Wheat (Durra sindie)			
	Light	Med	Heavy	None	Light	Med.	Heavy	None
Yetmen								
Plant disease	95.8							
Insect damage	94.1			5.9				
Weed damage	85.1	14.9		36.4				
Bird damage	61.2		2.5					
Wild animals damage	50.9			49.1				
Livestock eating/tram.	71.9	1.7	1.7	24.8				
Sirbana-Godeti								
Plant disease	90.9		2.0	4.1	89.8		1.1	2.3
Insect damage	79.2			19.3	77.3	2.3		19.3
Weed damage	81.2	1.0		17.3	79.5	2.3		18.2
Bird damage	63.5			34.0	67.0			31.8
Wild animals damage	66.5			31.5	62.5			35.2
Livestock eating/tram	75.4			24.6	74.7	2.3		23.0
Eteya								
Plant disease					83.7	11.6	4.8	
Insect damage					15.6	1.4		83.0
Weed damage					33.3		0.7	59.2
Bird damage					25.3	6.8	0.7	74.0
Wild animals damage					13.6	4.8		81.6
Livestock eating/tram					26.5	3.4		70.1

Source: Own computation

4.2.2. Input used and yield response

Input used and yield response have been treated under farmers' practice and extension plots, and technology combinations based on the recommended rate of fertilizer uses. In this regard, the first section deals with input used and yield responses of extension and farmers' practice plots and the second section with the technology combination of recommended rate of fertilizer application and other input types.

4.2.2.1. Yield response of technology combination on farmers' practice and extension plots[10]

In this section, plots of wheat and teff were divided into farmers' practice and extension. Furthermore, based on the use of input types, two technology combinations have been identified for both the farmers' practice and extension plots of wheat and teff. These technology combinations include (i) *medium technology*: fertilizer and local seed either from own previous harvest or purchased/exchanged from markets; and (ii) *superior technology*: fertilizer and improved seed either saved from previous harvest or newly bought.

4.2.2.1.1. Wheat plots

Table 13 presents patterns of input use and yield for all wheat plots planted under those technology combinations used by farmers. In terms of overall average application of seed, farmers applied 199 kg/ha and 148 kg/ha of local and improved seeds, respectively. These average applications of seed are almost equal to the recommended application of seed by Ministry of Agriculture (MoA). (The recommended application of seed is 200 kg/ha and 150 kg/ha when local and improved seed are used, respectively). In fact, more than 3% and 14% of the plots under farmers' practice in Eteya and Shashemene received more than 200kg/ha on average. The remaining plots under both farmers' practice and extension plots received less than the recommended application rate of seed. Although the average application of seed for medium technology farmers' practice plots in Eteya and Shashemene exceeded the recommended application, the highest portion of the plots were applied with average application of seed that lies within the range of 175 – 200 kg/ha (Table 13). Amazingly, most extension plots on average received less than or equal to 150 kg/ha.

The average application of seed on superior technology plots of wheat is less than medium technology plots. For instance, the average applications of seed on superior technology farmers'

[10] Plots under new extension program are considered as extension plots. The other plots are taken as farmers' practice plots.

practice and extension plots of Eteya and Shashemene were 178 and 141 kg/ha, and 127 and 121 kg/ha, respectively (it is less than the average application of seed on medium technology of either farmers' practice or extension plots). These high average applications of seed on medium technology, as compared to superior technology, may reflect the impurity or limited germination ability of the local seed [Gavaian and Gemechu, 1995]. Besides, most of the local seed was retained from previous harvest, either from own sources or purchased/exchanged from the market. The local seed that has been retained from the previous harvest contains a high proportion of weed seeds, as indicated by Chilot et. al, (1992), then farmers may be employing high seeding rate to stifle weed growth; furthermore, seed germination may be low due to poor storage conditions or insect infestation thus, necessitating the use of higher seed rates.

While the recommended rates of application for DAP chemical fertilizer is 100 kg/ha, only the wheat plots of Eteya, with the exception of medium technology extension plots, received near to the recommended rate (Table 13). Some exceptional average application rate was also reported in Shashemene. For instance, while the superior technology farmers' practice plots applied only (64 kg/ha) DAP chemical fertilizer, the superior technology extension plots of the same site received the highest (141 kg/ha). Generally, superior technology plots received DAP chemical fertilizer in the range of 60 - 99 kg/ha (less than the recommended rate) except the superior technology extension plots of Shashemene and Sirbana-Godeti.

The average application of urea chemical fertilizer in all sites did not show any consistency with the recommended rate (50 kg/ha). For example, as the average urea fertilizer application rate of medium technology farmers' practice plots of Eteya and Sirbana-Godeti were near the recommended rate (50 kg/ha), the same plots of Shashemene received more than the recommended rate (the plots received on average 64 kg/ha) (Table 13). The amount of urea that has been applied on medium technology extension plots of Eteya and Shashemene was by far greater than the recommended rate (82 and 83 kg/ha, respectively) whereas, similar plots in Sirbana-Godeti received only 36 kg/ha. The application rates of superior technology farmers' practice plots also vary from one site to another. It was 35, 58 and 62 kg/ha for Eteya, Shashemene and Sirbana-Godeti, respectively. Only superior technology extension plots of Sirbana-Godeti received near the recommended rate. Similar technology plots of Shashemene and Eteya received higher than the recommended rate (96 and 68 kg/ha). Despite the fluctuation on the average urea application, most of the plots under different technologies received less than or equal to the recommended rate (Table 13).

Another important input for crop production is herbicide. In the study sites, the average application of herbicide for all plots has been in the range of 0.32 lt/ha to 0.9 lt/ha. The lowest average application of herbicide was reported in superior technology farmers' practice plots of Sirbana-Godeti and the highest on superior technology extension plots of Eteya. If we look at each technology combinations, the average application of herbicide was the highest on Eteya plots followed by Sirbana-Godeti. Particularly, extension plots of Eteya received nearly 1 lt/ha.

On the average, 14, 14 and 13 qt/ha yield of wheat was obtained from farmers' practice plots of Eteya, Shashemene and Sirbana-Godeti, respectively. The yield responses of the extension plots of those sites were 17, 20 and 18 qt/ha, respectively (Annex I). In general, we can conclude that extension plots were better in yield responses than the farmers' practice plots. Moreover, the average application of seed was less for all extension plots than the farmers' practice plots.

Our expectation about yield responses between technology combinations leads us to the categorization of plots into high and medium technology. Thus, if we assess it across technology, the average yield responses (nearly 20 qt/ha) of superior technology extension plots of Eteya and Shashemene were better than any other technology combination. Superior technology farmers' practice plots are second in yield responses (18 qt/ha). In the case of Sirbana-Godeti, the yield responses from the medium technology farmers' practice plots were better than other technology combinations within the same site. From medium technology extension plots of Sirbana-Godeti, on average 21qt/ha yield was obtained. However, only three plots were found under this technology combination.

In general, the yield response of Eteya and Shashemene site was better. If we look across technology combinations, relatively less inputs and higher yield responses were obtained from superior technology extension plots.

TABLE 13: FARMERS' PRACTICE AND EXTENSION WHEAT PLOTS: INPUT USE AND YIELDS

	Eteya plots				Shashemene plots				Debreziet- Sirbana-Godeti plots			
	Farmers' practice		Extension		Farmers' practice		Extension		Farmers' practice		Extension	
	Mediu. Tech.	Superior Tech.	Mediu. Tech.	Superior Tech.	Mediu. Tech.	Superior Tech.	Mediu. Tech.	Superior Tech.	Mediu. Tech.	Superior Tech.	Mediu. Tech.	Superior Tech.
No. of plots for avg. appl. f seed	123	11	8	11	83	7	3	9	80	2	3	7
Avg. application of seed (kg/ha). (Standard. deviation)	206.34 (40.28)	178.18 (46.2)	154.7 (67.18)	141.14 (89.17)	234.51 (87.92)	127.14 (59.08)	155.56 (76.98)	121.11 (25.00)	156.00 (48.86)	150.00 (70.71)	66.67 (11.55)	158.00 (18.97)
Seeding rate (%)	100	100	100	100	100	100	100	100	100	100	100	100
<=150/ha	8.1	18.2	50	72.7	14.5	71.4	3.33	100	41.3	50	100	71.4
150.01 - 175 kg/ha	2.4	9.1	-	-	3.6	-	-	-	17.5	-	-	14.3
175.01 – 200 kg/ha	59.3	72.7	25	9.1	37.3	28.6	66.7	-	38.8	50	-	14.3
200.01 – 250 kg/ha	24.3	-	25	-	4.8	-	-	-	1.3	-	-	-
>250.01 kg/ha	5.7	-	-	18.2	39.8	-	-	-	1.3	-	-	-
Avg. application of DAP (kg/ha). (Standard deviation)	105.16 (39.13)	95.09 (11.4)	74.9 (34.84)	98.55 (55.00)	87.61 (40.10)	64.29 (24.40)	88.89 (19.00)	140.74 (57.00)	89.90 (38.64)	124.00 (107.48)	60.00 (12.00)	82.19 (30.72)
DAP application rates (%)	100	100	100	100	100	100	100	100	100	100	100	100
<=50 kg/ha	4.2	-	37.5	18.2	22	71.4	-	-	21.5	50	33.3	28.6
50.01- 75 kg/ha	10.2	9.1	12.5	9.1	12.2	-	33.3	11.1	15.2	-	66.7	28.6
75.01 - 100 kg/ha	63.6	90.9	37.5	63.6	57.3	28.6	66.7	44.4	49.4	-	-	28.6
100.01- 150 kg/ha	14.4	-	12.5	-	2.4	-	-	-	8.9	-	-	14.3
>150.01 kg/ha	7.6	-	-	9.1	6.1	-	-	44.4	5.1	50	-	-
Avg. application of Urea (kg/ha) (Standard deviation)	50.85 (44.27)	35.00 (10.0)	81.67 (60.00)	68.03 (30)	64.08 (29.97)	58.33 (20.41)	83.33 (24.00)	96.30 (11.00)	55.24 (24.00)	62.00 (53.74)	36.00 (20.78)	52.67 (35.72)
Urea application rates (%)	100	100	100	100	100	100	100	100	100	100	100	100
<=50 kg/ha	76.9	100	50	45.5	48	88.3	-	-	50.6	50.00	66.7	57.1
50.01 - 75 kg/ha	-	-	-	-	16	16.7	50	11.1	26.6	50	33.3	14.3
75.01 - 100 kg/ha	15.4	-	33.3	54.5	36	-	50	88.9	22.8	-	-	28.6
100.01- 150 kg/ha	3.8	-	-	-	-	-	-	-	-	-	-	-
>150.01 kg/ha	3.8	-	16.7	-	-	-	-	-	-	-	-	-
Avg. application of herbicide (l/ha)	0.65	0.55	0.79	0.90	0.57	0.4	0.67	0.45	0.47	0.32	0.68	0.82
Herbicide application (%)	100	100	100	100	100	100	100	100	100	100	100	100
<=0.2 l/ha	1.0	-	-	-	8.1	100	-	44.4	3.8	100	-	-
0.201 - 0.4 l/ha	39.0	50	-	20	50.0		33.3	22.2	59.6		-	-
0.401 - 0.6 l/ha	17.1	20	42.9	-	5.4		-	-	11.5		-	16.7
> 0.601 l/ha	42.9	30	57.1	80	36.5		66.70	33.3	25.0		100	83.3
Grain yields (kg/ha) (Standard deviation)	1439.21 (887.5)	1297 .00 (513.26)	1385.0 (717.0)	1922.42 (992.00)	1375.02 (678.61)	1842.29 (917.00)	1533.00 (115.00)	2066.67 (600.00)	1269.17 (760.00)	1400.00 (565.65)	2133.33 (960.00)	1742.86 (680.34)

4.2.2.1.2. Teff plots

Similar to wheat, the teff plots were also treated under two-technology combination, although we failed to find the superior technology plots due to absence of improved seed variety.

The average application rate of seed was 86 and 65 kg/ha and 60 and 66 kg/ha for Debrezeit-Sirbana-Godeti and Shashemene farmers' practice and extension plots, respectively. The average application rates of seed for Yetmen farmers' practice plots are less than any other plots (34 kg/ha) (Table 14). The highest average application of seed was reported for farmers' practice and extension plots of Sirbana-Godeti. This rate is by far greater than the average application of seed of the site studied by Julie A. et. al., (1999). According to their findings the application rate was 39 kg/ha for Qoladma, 41 kg/ha for Magna and 58 kg/ha for combination of Qoladma and Magna. Furthermore, most of the plots in Yetmen and the farmers' practice plots of Shashemene were planted within a range of 25– 50 kg of seed per hectare.

The average application of DAP fertilizer ranges from 86-93 kg/ha for farmers' practice plots. This rate was higher than the application rate for extension plots of Sribana-Godeti (51 kg/ha). This is also true for the extension plots of Shashemene (64 kg/ha).

The average application of urea was greater than the recommended rate for farmers' practice of all sites and extension plots of Shashemene though the difference did not seem significant (Table 14). Less than the recommended rate (34 kg/ha) was applied on extension plots of Sirbana-Godeti. Although the average application of urea was greater than the recommended rate in all farmers' practice plots, the largest parts of the plots were applied with less or equal to 50 kg/ha.

Besides, the average application rates of herbicide variation range between 0.45 lt/ha to 0.65 lt/ha (Table 14).

Even if the plots were divided into extension and farmers' practice, the yield responses of those technology combinations have not shown considerable differences. For example, the yield responses of extension plots of Sirbana-Godeti was nearly equal to the yield response of farmers' practice plots of the same site (nearly 10 qt/ha). Surprisingly, yield responses from extension plots of Shashemene (5 qt/ha) was less than the yield responses of farmers' practice plots (7qt/ha) of the same site (Table 14).

TABLE 14: FARMERS' PRACTICE AND EXTENSION TEFF PLOTS: INPUT USE AND YIELDS (ONLY LOCAL SEED WAS USED FOR BOTH FARMERS' PRACTICE AND EXTENSION PLOTS)

	Sirbana-Godeti		Yetmen		Shashemene	
	Farmers' practice	Extension	Farmers' practice	Extension	Farmers' practice	Extension
No. of plots for avg. application of seed	175	17	113	-	63	5
Avg. application of seed (kg/ha)	85.84 (41.42)	64.70 (36.00)	33.98 (8.35)	-	60.08 (44.86)	65.47 (21.42)
Seeding rate (%)	100	100	100	-	100	100
<=25 kg/ha	1.7	-	18.6	-	17.5	40
25.01 - 50 kg/ha	6.3	-	78.8	-	41.3	20
50.01 - 75 kg/ha	26.3	76.5	2.7	-	19.0	40
75.01 - 100 kg/ha	52.6	17.6	-	-	19.0	-
100.01 - 125 kg/ha	7.4	5.9	-	-	3.2	-
>125.01 kg/ha	5.7	-	-	-	-	-
Avg. application of DAP (kg/ha)	86.81 (29.90)	51.42 (22.50)	93.10 (39.30)	-	86.21 (39.30)	63.83 (38.17)
DAP application rates (%)	100	100	100	-	100	100
<=50 kg/ha	12.6	100	7.1	-	16.9	40
50.01 - 75 kg/ha	12.1	-	14.3	-	13.6	20
75.01 - 100 kg/ha	63.8	-	50.9	-	59.3	40
100.01- 150 kg/ha	8.0	-	24.1	-	5.1	-
>150.01 kg/ha	3.4	-	3.6	-	5.1	-
Avg. application of Urea (kg/ha)	55.31 (22.47)	34.21 (14.53)	58.83 (22.04)	-	66.67 (33.93)	56.25 (61.87)
Urea application rates (%)	100	100	100	-	100	100
<=50 kg/ha	49.4	100	41.6	-	45.5	50
50.01 - 75 kg/ha	28.8	-	35.4	-	9.1	50
75.01 - 100 kg/ha	20.6	-	20.4	-	45.5	-
100.01- 150 kg/ha	0.6	-	-	-	-	-
>150.01 kg/ha	0.6	-	-	-	-	-
Avg. application of herbicide (l/ha)	0.45	0.65	-		0.6	0.5
Herbicide application (%) if applied	100	100	-		100	100
<=0.2 l/ha	7.5	-	-		7.3	-
0.201 - 0.4 l/ha	56.7	5.9	-		52.7	40
0.401 - 0.6 l/ha	10.0	11.8	-		5.5	20
> 0.601 l/ha	25.8	82.4	-		34.5	40
Grain yields (kg/ha)	1010.29 (375.59)	1109.24 (385.48)	1048.97 (538.2)	-	619.56 (275.05)	514.67 (210.73)

Note: 1. The figures under parenthesis are standard deviations.
2. Source own computation

4.2.2.2. Input used and yield responses based on seed varieties and recommended rate of fertilizer.

The result of descriptive statistics, Table 15a and 15b, reveal that the yield response to chemical fertilizer with improved seed variety is higher than the responses to fertilizer with local seed varieties.

The yield responses of local seed varieties with at least the recommended rate of urea and DAP is better than local seed varieties with less than recommended rate for both teff and wheat. For instance, yield could be increased by 21 and 19 per cent in Eteya and Shashemene, respectively, if local seed of wheat was applied with at least recommended rate of DAP and Urea. The teff plots with similar packages in Yetmen resulted in 4 per cent increase in yield. In fact, almost equal yield of teff was obtained from local seed with any technology combination of fertilizer in Shashemene and Sirbana-Godeti. This was also true for wheat plots of Sirbana-Godeti.

Although the yield responses of improved seed varieties under any technology combination is better than any local seed technology combination, the response of improved seed with fertilizer technology combination did not give any clear pattern. For example, it was possible to obtain 47 per cent increase in yield responses due to application of improved seed with at least recommended rate of DAP and Urea in Eteya where as better yield responses were found from improved seed with less than the recommended rate of DAP and Urea in Shashemene and Sirbana-Godeti (8 and 51 % for Shashemene and Sirbana-Godeti, respectively).

TABLE 15A: AVERAGE APPLICATION OF SEED INPUTS, FERTILIZER APPLICATIONS AND YIELD RESPONSES OF WHEAT

Technology types	Eteya				Shashemene				Sirbana-Godeti			
	Yield (kg/ha)	Seed (kg/ha)	Fertilizer (kg/ha)		Yield (kg/ha)	Seed (kg/ha)	Fertilizer (kg/ha)		Yield (kg/ha)	Seed (kg/ha)	Fertilizer (kg/ha)	
			DAP	Urea			DAP	Urea			DAP	Urea
(1) Local seed plus (DAP + Urea >=150 kg/ha)	N=22 1782.73 (104.47)	N=22 221.21 (41.37)	N=22 135.33 (57.42)	N=22 52.42 (59.22)	N=18 1632.89 (861.02)	N=18 255.78 (77.74)	N=18 127.78 (46.09)	N=18 62.22 (43.73)	N=36 1235.19 (650.28)	N=36 167.41 (43.69)	N=36 114.70 (32.64)	N=36 71.19 (22.22)
(2) Local seed plus (DAP + Urea < 150 kg/ha)	N=102 1406.32 (820.80)	N=102 199.09 (42.37)	N=102 94.62 (23.69)	N=102 5.08 (16.16)	N=66 1320.61 (595.84)	N=66 225.57 (91.20)	N=66 76.53 (29.77)	N=66 8.31 (18.31)	N=46 1357.97 (852.75	N=46 142.09 (53.98)	N=46 59.96 (21.45)	N=46 41.50 (16.12)
(3) Improved seed plus (DAP + Urea >=150 kg/ha)	N=6 2436.67 (752.64)	N=6 190.83 (76.19	N=6 121.67 (63.38)	N=6 86.67 (24.22)	N=9 1899.56 (887.02)	N=9 132.22 (34.92)	N=9 144.44 (52.70)	N=9 100.00 (0.0)	N=4 1050.00 (191.5)	N=4 149.00 (40.84)	N=4 133.33 (47.14)	N=4 91.67 (16.67)
(4) Improved seed plus (DAP + Urea < 150 kg/ha)	N=16 1299.58 (641.27)	N=16 147.97 (68.99)	N=16 87.50 (20.74)	N=16 23.02 (24.44)	N=7 2057.14 (538.07)	N=7 112.86 (49.90)	N=7 59.52 (18.90)	N=7 45.24 (20.89)	N=5 2160.00 (328.63)	N=5 162.00 (21.68)	N=5 58.00 (12.81)	N=5 25.20 (2.68)

TABLE 15B: AVERAGE APPLICATION OF SEED INPUTS, FERTILIZER APPLICATIONS AND YIELD RESPONSES OF TEFF

Technology types	Yetmen				Shashemene				Sirbana-Godeti			
	Yield (kg/ha)	Seed (kg/ha)	Fertilizer (kg/ha)		Yield (kg/ha)	Seed (kg/ha)	Fertilizer (kg/ha)		Yield (kg/ha)	Seed (kg/ha)	Fertilizer (kg/ha)	
			DAP	Urea			DAP	Urea			DAP	Urea
(1) Local seed plus (DAP + Urea >=150 kg/ha)	N=65 1137.90 (240.00)	N=65 35.28 (20.0)	N=65 112.12 (80.00)	N=65 69.84 (48.00)	N=12 600.00 (240.00)	N=12 80.67 (20.00)	N=12 125.83 (80.00)	N=12 58.33 (0.00)	N=78 1027.69 (400.00)	N=78 103.31 (24.00)	N=78 108.19 (76.00)	N=78 69.85 (40.00)
(2) Local seed plus (DAP + Urea < 150 kg/ha)	N=113 1098.97 (240.00)	N=113 33.98 (20.00)	N=113 93.10 (1.33)	N=113 58.83 (4.00)	N=68 611.84 (192.00)	N=68 60.48 (20.00)	N=68 78.23 (0.00)	N=68 13.42 (0.00)	N=192 1019.05 (400.00)	N=192 92.01 (20.00)	N=192 82.77 (0.00)	N=192 52.00 (0.00)

Note: 1. N= number of plots
2. The figures in the parenthesis are standard deviations

As we can see from Table 15, the yield response of improved seed varieties is higher than local seed inputs. However, only few plots of wheat and no plot of teff were applied with improved seed (the share of improved seed obtained from previous harvest is higher than newly bought). For the technology to be effective in yield responses, like the "Green Revolution" in East Asia, the application of improved seed varieties (high yielding varieties) is essential. Nevertheless, due to different constraints such as lack of cash for down payment, inaccessibility of credit, too much expensiveness of the packages, etc farmers refrain from using newly bought and recommended rate of fertilizer (Table 16).

TABLE16: MAJOR REASONS OF NOT USING IMPROVED SEED VARIETIES OF WHEAT (IN %).

Major reasons	Percentage of household responses			
	Sirbana-Godti	Shashemene	Eteya	Yetmen
Lack of cash for down payment	31	34	10.0	4.2
High costs	42.3	28.9	42.5	66.7
Lack of credit	-	17.3	12.5	-
No supply	26.7	19.8	1.2	12.5

Source: own computation

4.3. Definitions of variables

The following variables are used in the regression analysis of either teff or wheat productivity.

a) Dependent variable

Yield = (in kg/ha), the quantity of yield obtained (in kg/ha).

b) Independent variables

1) Seed = Quantity of local or improved seed used (in kg/ha).

2) DAP = Quantity of chemical fertilizer, DAP used (in kg/ha).

3) Urea = Quantity of chemical fertilizer, Urea used (in kg/ha).

4) Herbicide = Quantity of herbicide used (in kg/ha)

5) Seedummy = 1 if improved seed was used (in kg/ha), 0 otherwise,

6) techdummy = 1 if recommended rate of DAP and Urea are used (DAP>= 100 kg/ha and Urea >= 50 kg/ha), 0 otherwise.

7) Dnplow = 1 if the plots were cultivated >= 4 times, 0 otherwise.

8) Dnweed = 1 if the plots were weeded >= 2 times, 0 otherwise.

9) Dtimfarm = 1 if land preparation, weeding, and harvesting was performed at normal time, 0 otherwise.

10) Dcropdam = 1 if crop damage was reported due to insect, bird, frost, flood, etc, 0 otherwise.

11) Edhh = Education of household head, 0 if illiterate, 1 if 1 to 6 years of education, 2 if 7 to 8 years of education and 3 if greater than eight years of education.

12) Doffarm = 1 if the household head was participated in off-farm activity, 0 otherwise.

13) Age =Age of household head in years.

14) Dsex = Sex of the household head. 1= male, 0 = female.

15) Fmsize = Potential active member of the family.

16) Lharvst = Labor used for harvesting (in adult men equivalent).

17) Lprepa = Labor used of land preparation (in adult men equivalent).

18) Dcroprota =1 if crop rotation with legumes plants was practiced in the last three years, 0 otherwise.

19) Dexten = 1 if the plots were under new extension, 0 otherwise.

20) Dlandquality = 1 if the quality of the land is "lem", 0 otherwise.

4.4. Regression results

A number of technological, environmental and farming practice variables were used in the regression model. Yields of teff and wheat were regressed on variables such as quantity of seed and chemical fertilizers (DAP and Urea), number of plowing and weeding, time of planting, weeding and harvesting, farmers' assessment about land quality, crop damage etc.

The specific variables and a priori expectations used in the regression are:

- **Seed:** is the quantity of local and/or improved seed used (in kg/ha) for production. It is hypothesized that better seed quality (improved seed) will give better yield response. Thus, the quality of seed would positively influence yield response.
- **DAP and Urea:** are chemical fertilizers used (in kg/ha) to increase soil fertility. Farmers increase their demand for chemical fertilizer when their plots become less fertile (for instance, due to intensive cultivation). For such types of plots, it is hypothesized that the consumption of chemical fertilizer would bring positive increment in production.
- **Herbicide:** Chemical used (in lt/ha) to control weeds. It is expected to have a positive impact on productivity.
- **Age of farm household head:** Age of the household head is one of the major factors for gaining experience in farming and learning the benefits of improved technology. This means that age of household head and yield responses are positively related to each other.
- **Household family size (adult men equivalent):** It represents the number of potential active family members participating in agricultural activity. Farming practices (management) mainly rely on the family labor. Thus, the family size of a household is expected to have a positive impact on productivity.

- **Number of oxen owned by the household head (in TLU):** Farming management (practices), particularly land preparation, is conducted by at least a pair of oxen. Thus, number of oxen of the household head is expected to have a positive impact on productivity.
- **Education level of the household head:** For most of the farming households, the decision about what to produce was made by the household head. This implies that the education level of the household head would have a significant impact on productivity of improved technologies.
- **Off- farm activity**: If income from off-farm activity is higher than the income from agricultural activity, farmers will prefer to spend less time on farming management. Therefore, it is expected to have negative impact on productivity.
- **Number of plowing and weeding:** Frequent plowing and weeding are used as a means of increasing aeration and weed control. Hence, the numbers of times these activities are carried out expected to have a positive impact on productivity.
- **Time of farming activities:** Timely operations of farming activities (land preparation, planting, weeding and harvesting) are expected to have a positive impact on productivity.
- **Crop rotation:** Crop rotation is one of the mechanisms to maintain the soil fertility of the land. Thus, it is expected to have a positive impact on productivity.
- **Crop damage:** refers to the damage caused by insects, birds, plant diseases, frost, flood etc. It is expected to have a negative impact on productivity.
- **Extension plots:** refers to the plots treated under new extension system. If plots are treated under extension agents, farmers are expected to employ proper farm management, recommended quantity of improved seed and fertilizer, herbicide, etc which is used to increase productivity.

- **Quality of land:** Good yield response depends on good quality of land. Hence, it is expected to have a positive impact on productivity.

To analyze the factors associated with the variability in teff and wheat yields absorbed in Eteya, Sirbana-Godeti, Shashemene and Yetmen the Cobb Douglass production function is employed. In addition, the multicollinearity problem is tested using Variance Inflation Factors (VIF). According to Green [1980:48,], multicollinearity would not be taken as problem if VIF is less than or equal to 2 (see Annex III for multicollinerity and heteroscadesticity test).

4.4.1. Eteya[11].

The key findings of the econometric results are depicted in Table 17. The quantity of seed and chemical fertilizer, DAP, (in kg/ha) are technological variables that positively and significantly influenced yield variability. Particularly, quantity of improved seed and at least the recommended rate of DAP and Urea have the same positive and significant impacts on yield.

To assess the contribution of farming practices on yield, a number of variables such as crop rotation, number of plowing, time of land preparation, weeding and harvesting is considered. Cultivating the plots at least four times and performing farming activities on time (land preparation, weeding and harvesting) are observed to have a positive and significant impact on yield. Land quality, age and sex of the household head are also found to be positively and significantly influence yield. As expected, off-farm activities have negative and significant impact on yield of wheat.

Although labor (adult equivalent) and number of oxen are of critical importance, both are found to be statistically insignificant. The impact of these variables may be captured by other variables such as number of plowing, timely operation of farming practices, which are already found to be significant for determinants of yield variation. It is obvious that none of these activities are conducted without labor, oxen or both. In addition, traditional labor arrangements such as "debo", "wenfel" etc., practiced particularly during peak seasons might undermine the significance of labor. As stated in the descriptive analysis, most of the farmers who face labor shortage use "wonfel", "debo" or both. Similar to labor, there is a traditional arrangement of sharing oxen either through "mekenajo" or exchange of labor days for oxen (see descriptive statistics). Generally, it can be concluded that the effects of labor and oxen number are captured by other related significant variables or by traditional sharing arrangements.

Storm/wind is an environmental variable that influence wheat yield variation negatively and significantly. Lastly, the explaining powers of the variables under consideration for yield variation are nearly 57 %.

[11] Only wheat crops were considered for this site

TABLE 17: RESULTS OF YIELD DETERMINANT MODEL FOR ETEYA PLOTS

Variable	Wheat				
	Coefficients	S.E.	T	Sig.	VIF
(Constant)	5.677	1.109	5.117	0.000	
Ln (seed)	0.287	0.158	1.812	0.073	1.367
Seeddummy: *1 repr. improved seed used*	0.260	0.102	2.541	0.012	1.457
Ln (DAP)	0.158	0.040	3.916	0.000	1.525
Ln (Urea)	-0.008	0.028	-1.267	0.572	1.334
Ln (herbicide)	-0.008	0.071	-1.093	0.277	1.291
Techdummy: *1rep. DAP >=100 &urea >=50 kg/ha*	0.486	0.139	3.494	0.001	1.804
Ln (age)	0.480	0.118	4.077	0.000	1.525
Ln(total labor)	-0.003	0.054	-0.552	0.582	1.439
Doxen: 1 rep.>=2 oxen	-0.006	0.074	-0.875	0.384	1.450
Dsex	0.533	0.122	4.360	0.000	1.290
Dcrop rotation	0.002	0.067	0.301	0.764	1.247
Doffarm	-0.219	0.092	-2.393	0.018	1.274
Dexten: 1=Land under ext.	0.174	0.113	1.541	0.126	1.374
Dnplow: *1 represents >=4 times plowing*	0.292	0.067	4.364	0.000	1.222
Dnweeding: 1 rep. twice weeding.	0.008	0.074	1.091	0.657	1.523
Dlandqulity: 1= "Lem"	0.155	0.076	2.048	0.043	1.271
Dtfarm: 1= normal	0.500	0.171	2.920	0.004	1.207
Rainfall near harvest	-0.008	0.070	-1.124	0.263	1.345
Storm/wind	-0.255	0.073	-3.512	0.001	1.251
N =	143				
Adjusted R.Sq.	56.9%				
F-stat =	10.317, significant				

Note: Ln (yield) = Dependent variable.

4.4.2. Sirbana-Godeti

The econometric results reveal that quantity of chemical fertilizer, DAP, (in kg/ha) has positive and significant impact on teff and wheat yields. Quantity of seed (improved seed) and at least the recommended rate of DAP and Urea have positive and significant contribution on yield of wheat at 5% level of significance. On the other hand, the contributions of these variables are negative and significant on yield of teff at 0.1% level of significance (Table 18). Herbicide application (in lt/ha) has positive and significant impact on teff yield. The contribution of chemical fertilizer, Urea, (in kg/ha) for yield variation across plots was not significantly different from zero either at 5% or 10% level of significance for both crops.

The impact of farming practices on productivity can be measured by number of variables such as crop rotation, frequency of plowing and weeding and tenure type for both crops. Accordingly, cultivating land at least four times and crop rotation are observed to have a positive and significant impact on teff yield at 0.1% and 10% level of significance, respectively. Land tenure and weeding plots twice have the same positive effect on wheat crop. It should be noted that frequent cultivation of the land could be used to control weeds and increase aeration of the soil. Moreover, crop rotation can maintain soil fertility.

If an individual household cultivates his own land (land tenure), he is likely to invest on upgrading the quality of the land for next harvesting season, perhaps through conservation practices and/or the use of organic manure. Manure helps to maintain the soil fertility through adding micro-nutrients such as magnesium, iron, calcium, etc, which are found in very small proportion but have significant impact on plant germination and growth.

Labor and number of oxen are traditional inputs (ingredients) for agricultural production. As expected, number of oxen has a positive and significant contribution on yield of both crops. Family labor (in adult equivalent) for harvesting has the same positive effect for wheat but its contribution is not statistically different from zero for teff. Furthermore, sex and education level of the household head have a positive impact on yield of both crops at 5% level of significance. Rainfalls near harvesting seasons and crop damage due to frost have negative and significant contribution for teff and wheat yields, respectively, at 10% level of significance. Moreover, off-farm activities influence yield variability of both crops negatively and significantly. Finally, the power of the regression variables to explain the yield variability of teff and wheat is about 69% and 62%, respectively.

TABLE 18: RESULTS OF YIELD DETERMINANT MODEL FOR SIRBANA-GODETI PLOTS

	Teff					Wheat				
Variable	Coeff.	S.E.	T	Sig.	VIF	Coeff	S.E.	T	Sig.	VIF
(Constant)	4.907	0.344	14.28	0.000		5.942	0.462	12.85	0.000	
Ln (seed)	-0.160	0.042	-3.78	0.000	1.33	0.265	0.058	4.54	0.000	1.39
Seedummy: 1rep. improved seed						0.002	0.123	0.122	0.904	2.49
Ln (DAP)	0.369	0.038	9.64	0.000	2.19	0.003	0.075	2.294	0.025	1.98
Ln (Urea)	-0.002	0.026	-0.61	0.543	2.07	-0.121	0.053	-0.345	0.720	2.05
Ln (herbicide)	0.010	0.030	3.29	0.001	1.32					
Techdummy: *1= DAP> =100 and Urea >=50kg/ha*	-0.148	0.042	-3.51	0.001	1.98	0.157	0.080	1.956	0.055	2.77
Ln (age)	0.413	0.056	7.33	0.000	1.69					
Dsex	0.121	0.053	2.26	0.025	1.56	0.232	0.082	2.830	0.060	1.24
Doxen: *1 rep. two or more oxen*	0.117	0.042	2.78	0.006	1.37	0.344	0.093	3.680	0.000	1.60
Dcrop rotation	0.006	0.031	1.81	0.073	1.17	-0.008	0.058	-1.39	0.170	1.45
Deduhhead	0.134	0.017	7.91	0.000	1.67	0.157	0.032	4.91	0.000	2.29
Doffarm	-0.242	0.054	-4.46	0.000	1.32	-0.203	0.093	-2.176	0.033	1.29
Dnplow: *1 rep. >=4 times plow.*	0.149	0.042	3.52	0.001	1.12	0.005	0.058	0.796	0.429	1.41
Dnweed: *1 rep. twice weeding*						0.216	0.057	3.765	0.000	1.47
Ln(laborharvst)						0.102	0.035	2.885	0.005	1.33
Dtlandpr: *1 if normal*	0.118	0.082	1.43	0.155	1.51					
Landaquestion: *1 rep.cult. his own.*						0.216	0.125	1.729	0.089	1.69
Rainfall near harvest	-0.009	0.034	-2.62	0.010	1.42					
Damage due to frost						-0.231	0.084	-2.743	0.008	1.78
N =	191					88				
Adju. R.Sq.	68.6%					62.4%				
F-stat =	22.281, Significant					8.994, Significant				

Note: Ln (yield) = Dependent variable.

4.4.3. Shashemene

Quantity of improved seed and chemical fertilizer, DAP, (in qt/ha), crop rotation and oxen number have positive and statistically significant impact on wheat yield. The contribution of herbicide, at least the recommended rate of DAP and Urea, number of plowing and land under extension agents have the expected positive sign, although their coefficients are not statistically different from zero (Table 19).

The quantity of local seed and application of DAP and Urea at recommended rate or more (in kg/ha), age and education level of the household head are found to be the most important and statistically significant variables in explaining teff yield variability. Though they are statistically insignificant, treating land under new extension system and land tenures have positive impact on yield. The other variables such as Urea, labor and sex of the household head, aren't found to have significant contribution to yield variation of both teff and wheat crops. Finally, the variables explain 32% and 35% of the total variation of teff and wheat yields, respectively.

TABLE 19: RESULTS OF YIELD DETERMINANT MODEL FOR SHASHEMENE PLOTS

	Teff					Wheat				
Variable	Coeff.	S.E.	T	Sig.	VIF	Coeff	S.E.	T	Sig.	VIF
(Constant)	2.468	0.872	2.829	.007		7.026	0.506	13.88	0.000	
Ln (seed)	0.348	0.100	3.467	0.001	1.23	0.003	0.063	0.477	0.635	1.18
Seedummy: 1= Improved seed						0.308	0.142	2.161	0.034	2.73
Ln (DAP)	-0.002	0.004	-0.346	0.731	1.31	0.009	0.054	1.564	0.100	1.26
Ln (Urea)	-0.458	0.041	-1.129	0.264	1.81	-0.002	0.025	-0.657	0.513	2.83
Ln (herbicide)						0.004	0.029	1.430	0.157	1.30
Techdummy: *1= DAP> =100 and Urea >=50kg/ha*	0.534	0.287	1.861	0.069	2.28	0.008	0.132	0.637	0.52	3.06
Ln (Total labor)	-0.010	0.088	-1.091	0.280	1.59	0.0003	0.005	0.053	0.877	1.14
Ln (age)	0.667	0.204	3.266	0.002	1.54	0.165	0.166	1.67	0.09	1.35
Dsex	-0.008	0.121	-0.620	0.538	1.23					
Doxen: *1 rep. two or more oxen*	0.002	0.119	-0.188	0.851	1.39	0.261	0.070	3.714	0.000	1.24
Dcrop rotation						0.253	0.069	3.690	0.00	1.17
Deduhhead	0.239	0.050	4.753	0.000	1.68					
Dextension	0.425	0.271	1.569	0.153	1.64	0.009	0.152	0.56	0.577	2.53
Dlandaquest: *1 rep. cul. his own*	0.121	0.192	0.632	0.530	1.20					
Dnplwing: *1 rep. twice weeding*						0.007	0.073	0.94	0.349	1.20
N =	67					98				
Adju. R.Sq.	31.7					35.2				
F-stat =	3.159,Significant					4.63, Significant				

Note: Ln (yield) = Dependent variable.

4.4.4. Yetmen[12]

Urea is the only technological variable that explains yield variability at 10% level of significance at this site. While oxen number, labor and land quality have positive and significant contribution, off-farm activities is observed to have a negative and significant impact on teff yield. The contribution of other variables, such as quantity of seed and recommended rate of DAP and Urea, age of household head and crop rotation is not significantly different from zero. However, some of these variables (including quantity of DAP and number of plowing) have the expected positive sign (Table 20).

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[12] Only teff plots were considered in this site.

TABLE 20: RESULTS OF YIELD DETERMINANTS MODEL FOR YETMEN PLOTS

Variable	Teff				
	Coefficients	S.E.	T	Sig.	VIF
(Constant)	6.778	0.749	9.049	0.000	
Ln (seed)	-0.0067	0.138	-0.489	0.627	1.183
Ln (DAP)	0.009	0.053	0.169	0.866	1.432
Ln (Urea)	0.183	0.090	2.035	0.045	1.535
Techdummy: *1rep. DAP >=100 &urea >=50 kg/ha*	-0.001	0.084	-1.182	0.24	1.633
Ln (age)	-0.005	0.125	-0.437	0.663	1.183
Ln(total labor)	0.108	0.059	1.814	0.073	1.227
Doxen: 1 rep.>=2 oxen	0.356	0.152	2.345	0.021	1.156
Doffarm	-0.595	0.160	-3.721	0.000	1.082
Dsex					
Dcrop rotation	-0.006	0.075	-0.771	0.0442	1.169
Dnplow: *1 represents >=4 times plowing*	0.001	0.097	0.113	0.91	1.344
Dlandqulity: 1= "Lem"	0.201	0.076	2.655	0.009	1.14
N =	112				
Adjusted R.Sq.	36.1				
F-stat =	5.934, Significant				

Note: Ln (yield) = Dependent variable.

4.5. Impact of improved technologies on profitability of Wheat and Teff

A partial budget analysis showed that improved technology of teff and wheat are profitable under both extension and farmers' practice plots at Sirbana-Godeti (with or without land cost) (Table 21). The net return (excluding land cost) was 1853 and 1777 Birr per ha for farmers' practice and 2552 and 2467 Birr per ha for extension plots of teff and wheat, respectively. This net return declined by more than half (596, 520, 1295 and 1210 Birr per ha for farmers' practices and extension plot of teff and wheat, respectively) when land costs are taken into account.

Further partial budget analysis in Birr per manday per ha also reveal that the net return (without land cost) was 22 and 30 Birr per manday per ha for farmers' practice and 21 and 29 Birr per mandays per ha for extension plots of teff and wheat, respectively. The return after deducting land cost, declined to 7 and 15 Birr per mandays per ha for farmers' practice plots and to 8 and 7 Birr per manday per ha for extension plots of teff and wheat plots respectively. These returns were higher than local market wage rate (6 Birr per day), implying that landless farmers can get more profit, under existing technology, if they rented-in land than hired out their labor. Furthermore, the opportunity cost of wheat production (compared to teff) is almost zero for farmers' practice plots and 2 Birr per manday per ha for extension plots of the site.

Similarly, the net return (excluding land cost) was 3188 and 2152 Birr per ha for farmers' practice and extension wheat plots at Shashemene. The marginal return and cost of extension wheat plots (compared to farmers' practice wheat plots) were 1106 and 69 Birr per ha, respectively. Thus, 130% profit can be obtained if extension agent managed wheat plots as per the recommended practices. The net return (including land cost) was 26 Birr per manday per ha, which is more than three folds of the local market wage rate (8 Birr per day).

Excluding land cost, the existing technology was found profitable for survey sites. For instance, the net return was 13 and 14 Birr per mandy per ha for farmers' practice and extension wheat plots at Eteya, respectively. It was 19 and 14, Birr per mandays per ha for farmers' practice and extension teff plots, respectively, while 45 and 69 Birr per mandy per ha for farmers practice and extension wheat plots, respectively, at Shshemene. Farmers' practice at Yetmen gave 14 Birr per manday per ha. Furthermore, at Eteya and Shahemene, the net return per manday per ha of extension wheat plots was better than the farmers' practice wheat plots. In fact, the net return from extension wheat plots at Shashemene was higher than any other sites.

When land cost was included, the existing technologies are profitable if and only if they cultivate their own land (except Sirbana-Godeti plots and Shashemene extension wheat plots). Thus, landless farmers would get more benefit if they hired out their labor than rented-in land for cultivation, because the local market wage rate (8, 7 and 6 Birr per day at Eteya, Shashemene and Yetmen, respectively) is higher than the net return from cultivation (Table21).

TABLE 21: PARTIAL BUDGET ANALYSIS OF TEFF AND WHEAT CROPS.

	Sirbana-Godeti				Eteya		Shashemene				Yetmen
	Teff		Wheat		Wheat		Teff		Wheat		Teff
Budget item	Farmers' practice	Extension plots	Farmers' practice	Extension plots	Farmers' practice	Extension plots	Farmers' practice	Extension Plots	Farmers' practice	Extension plots	Farmers' practice
Number of plots	175	17	80	9	129	15	63	5	88	11	113
Yield in (kg/ha)	1010.29	1109.24	1374.5	1733.33	1436.78	1474.67	619.56	514.67	1442.12	1963.64	1094.49
Yield value (Birr/ha)	2950.51	3527.06	2831.47	3570.67	2370.69	2433.2	1547.71	1291.81	3057.3	4162.91	1685.52
Input costs (Birr/ha)	580.99	393.82	567.84	522.37	799.73	790.57	486.47	431.67	698.19	780.84	387.5
-Seed inputs	272.91	190.66	252.02	268.43	434.17	414.94	150.16	164.32	385.46	317.44	52.29
-DAP	184.03	109.02	188.4	135.68	256.68	215.6	198.29	146.82	200.64	306.67	230.25
-Urea	102.87	63.63	104.01	83.08	76.97	123.17	113.33	95.63	86.99	135.33	104.96
-Herbicide	21.18	30.51	23.41	35.18	31.91	36.86	24.69	24.9	25.1	21.4	
Land costs (Birr/ha)	1257	1257	1257	1257	1163.63	1163.63	2000	2000	2000	2000	667.67
Wage labor (Birr/ha)	103.2	103.2	103.2	103.2	83.25	83.25	100.51	100.51	100.51	100.51	8.45
Animals traction (Birr/ha)	413.48	477.78	383.42	477.78	333.42	334.29	99.64	106.28	106.28	93.23	306.11
Net return in Birr per ha (excluding land cost)	1852.84	2552.26	1777.01	2467.32	1154.29	1225.09	861.09	653.35	2152.32	3188.33	983.46
Net return in Birr per ha (including land cost)	595.84	1295.26	520.01	1210.32	-9.34	61.46	-1138.91	-1346.65	152.32	1188.33	315.79
Net return in Birr per manday per ha (excluding land cost).	21.89	30.16	21.00	29.15	13.03	13.83	18.75	14.22	46.86	69.42	13.49
Net return in Birr per manday per ha (including land cost)	7.04	15.30	7.49	17.43	-	0.69	-	-	3.32	25.87	4.33

Source: Own computation.

V. SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

5.1. Summary and conclusion

The lessons from the "Green revolution" in East Asia reveal that appropriate farming practices (management) and intensive utilization of improved technologies such as high yielding varieties (HYV), chemical fertilizers (Urea and DAP), herbicides, pesticides as well as irrigation technology greatly influence crop yield.

The government of Ethiopia has made an effort to introduce and implement agricultural technologies to increase foodgrain production. This study has tried to assess the availability of technology at the farm level and whether farmers who apply these technologies obtain adequate return.

The study considered wheat and teff because they are staple food for most people in the country. The study sites, namely Sirbana-Godeti, Eteya, Shashemene and Yetmen, were selected because they have larger teff/wheat plots and greater access to improved technology.

The descriptive statistical analysis, using the classification of medium versus superior technology of farmers' practice and extension plots revealed that extension plots utilized lower seeding rate and respond better yield than farmers' practices. Furthermore, the yield responses of superior technology extension plots are better than any other technology combinations. Similarly, the descriptive statistical analysis based on recommended rate of fertilizer application also indicated that the yield response of improved seed with fertilizer is better than any other combinations.

Different factors that influence the productivity of improved technologies were assessed using Cobb-Douglas production function. Farming practices (management), technological and environmental factors do influence productivity of teff and wheat although the magnitude of their influence varies from site to site. The estimated Cobb-Douglas model indicated that factors that significantly determine the productivity of improved technologies of teff in Sribana-Godeti are DAP, herbicide, age, sex and education level of the household head, oxen number, crop rotation, number of plowing, off-farming and crop damage. With regard to wheat, the productivity was significantly influenced by quantity of seed and DAP, recommended rate of chemical fertilizer, sex and education level of the household head, oxen number, labor for harvesting, land tenure and crop damage.

In Eteya the quantity of improved seed, DAP, recommended rate of chemical fertilizer, sex and age of household head, number of plowing, time of farming activities (land preparation, harvesting and weeding), land quality and crop damage have a significant impact on productivity. In Shashemene, while the quantity of local seed and recommended rate chemical fertilizer, age and education level of the household head have significant contribution on productivity of teff, the quantity of improved seed, application of DAP, oxen number and crop rotation have significant effect on productivity of wheat. Lastly, urea, off-farm activity, land quality and labor have significant influence on productivity of teff in Eteya.

Analysis of the different factors that influence productivity of technologies may not necessarily indicate profitability of technologies. Therefore, analyzing the profitability of those technologies would be indispensable. The partial budget analysis, without land cost, indicated that the existing technologies are profitable for both teff and wheat crops. Moreover, profits from extension plots are higher than farmers' practice plots. The existing selected technologies are unprofitable when land cost is deducted except for crops in Sirbana-Godeti. In other words, the net return per mandays per hectare is less than the market wage rate. The existing technologies are generally unprofitable for those that depend on rented land.

In general, regression and descriptive analysis results showed that productivity is highly influenced by quantity of improved seed used, chemical fertilizers, farming practices (management) such as number of plowing, weeding, time of land preparation, weeding and harvesting etc. However, the number of individual households who used improved seed was very few. There is a need for improved technologies, particularly improved seed, to promote agricultural production.

5.2. Policy implications

Several policies that could improve productivity and profitability of wheat and teff technologies can be suggested. First, improved seed varieties are found to be statistically significant for increasing productivity. Nonetheless, only few wheat farmers used improved seed. The multiplication and dissemination of improved seed varieties should be given a high priority. Since lack of credit has also contributed to limited use of wheat seeds, microfiniance institutions should be expanded to reach the farmers and extend credit needs to buy improved technology.

Second, fertilizer is highly significant in nearly all yield equations. Measures should therefore be taken to ensure timely availability and widespread used of fertilizer. The current market of fertilizer is distorted and inefficient [Mulat, 1995]. Moreover, fertilizer is currently available in 50 kg bags only and this quantity may be not affordable to poor and disadvantaged farm households. Individual households who only have the capacity to cultivate less than half hectare are forced to buy 50 kg bag of DAP or urea thereby incurring unnecessary extra cost. Thus, fertilizer should be packed in less than 50kg bags (say 10, 15, 20, 25, 30, 35, 40 and 45). Such small bagging combined with other affordable packages of improved seed, herbicide, pesticides etc, can help resource poor farmers to use more fertilizer.

Third, availability of technology alone may not result in high productivity and profitability. Farm output may be affected by different exogenous factors such as excess of rainfall, wind/storm, rust, crop damage due to insects, birds etc. This indicates the necessity of crop insurance. Even though there are no insurance companies that insure crop damage, the government should introduce incentive schemes to encourage crop insurance.

Fourth, a reform on the present land tenure system is necessary. The resource poor and disadvantaged farmers should be given full right on their land including transfer of ownership.

Fifth, numbers of plowing and weeding, time of farming activity (land preparation, weeding and harvesting) are farm management activities that influence productivity. Farmers must be trained to improve their farm management capacities. Thus, the government should design and deliver proper farm management training program to farmers.

Six, traditional farm practices such as crop rotation, fallowing and manure application help to retain fertility of land. Due attention should be given to preserve such useful traditional practice in the extension program.

Annex I: Average input used and yields for farmers' practices and extension wheat plots (aggregation of the two technology)

	Eteya plots		Shashemene plots		Debreziet – Sirbana Godeti plots	
	Farmers' practice	Extension	Farmers' practice	Extension	Farmers' practice	Extension
No. of plots for avg. application of seed	129	15	88	11	80	9
Avg. application of seed (kg/ha)	203.59 (34.87)	166.01 (68.67)	226.91 (90.47)	141.52 (38.19)	157.28 (49.97)	145.11 (48.72)
Seeding rate (%)	100	100	100	100	100	100
<=150 kg/ha	7.8	53.3	18.2	72.7	40	66.7
150.01 -175 kg/ha	3.1	-	3.4	9.1	17.5	11.1
175.01 - 100 kg/ha	62.0	20.0	37.5	18.2	38.8	11.1
100.01 - 150 kg/ha	23.3	20.0	4.5	-	2.5	11.1
>150.01 kg/ha	3.9	6.7	36.4	-	1.3	-
Avg. application of DAP (kg/ha)	103.3 (33.85)	75.93 (29.52)	86.48 (39.10)	133.33 (54.00)	84.24 (38.82)	75.93 (29.52)
DAP application rates (%)	100	100	100	100	100	100
<=50 kg/ha	4.0	26.7	25.3	-	22.8	33.3
50.01 - 75 kg/ha	9.7	6.7	11.5	9.1	15.2	33.3
75.01 - 100 kg/ha	66.01	53.3	55.2	54.5	48.1	22.2
100.01- 150 kg/ha	13.7	6.7	2.3	-	8.9	11.1
>150.01 kg/ha	6.5	6.7	5.7	36.4	5.1	-
Avg. application of Urea (kg/ha)	47.21 (41.90)	72.18 (47.09)	61.73 (27.78)	96.67 (10.54)	55.03 (24.17)	50.30 (32.56)
Urea application rates (%)	100	100	100	100	100	100
<=50 kg/ha	82.1	53.8	56.7	-	50.6	55.6
50.01 - 75 kg/ha	-	-	11.3	10.0	26.6	22.2
75.01 - 100 kg/ha	10.7	38.5	30.0	90.0	22.8	22.2
100.01- 150 kg/ha	3.6	7.7	-	-	-	-
>150.01 kg/ha	3.6	-	-	-	-	-
Avg. application of herbicide (l/ha)	0.64	0.8	0.55	0.48	0.47	0.8
Herbicide application (%) if applied	100	100	100	100	100	100
<=0.2 l/ha	48.7	-	87.5	36.4	83.0	-
0.201 - 0.4 l/ha	25.2	14.3	11.3	27.3	13.2	-
0.401 - 0.6 l/ha	13.0	21.4	-	-	3.8	14.3
> 0.601 l/ha	13.0	64.3	1.3	36.4	-	85.7
Grain yields (kg/ha)	1424.05 (807.70)	1743.11 (932.00)	1423.58 (700.30)	1963.64 (585.00)	1284.17 (758.66)	1844.44 (630.70)

Note: 1. The figures under parenthesis are standard deviations.
2. Source: Own computation

Annex II. Labor Equivalent (LE)

The most important source of work force for peasant household is determined by size, age, and gender composition of the households. The family size itself could serve as a crude measure of LE. However, the fact that working capacity is deferent according to the age and gender category meant that a standardized measure is necessary to make comparison. A recent study (Gaspart et al. 1998:173) on rural; Ethiopia assigns a unitary weight to all household members aged between 6 and 14. However, taking into account the labor allocation pattern of different household members for farm and related work, it is conceivable for differences in LE to prevail not only across age groups but also between genders. The following categorization of conversion factor is developed compromising between Johnson (1982), Ruthenberg (1983) and that of Gasper et al. (1998).

	Gender	
Age group (years)	Male	Female
Below 10	0.0	0.0
10-13	0.2	0.2
14-16	0.5	0.4
17-50	1.0	0.8
Over 50	0.7	0.5

Source: Development Strategies and the Ethiopian Peasantry: Supply response and Rural differentiation. Ababe Haile Gebriel a P.HD thesis submitted to The Hague, the Netherlands, 1999.

Annex 1II: Econometric tests

Multicollinearity and hetroscadesiticity are the major problems of cross-sectional data. Therefore, looking at these problems is essential since their occurrence might lead to insignificance of the coefficient of the most important variables. The SPSS econometric package allows us to test these problems through Variance Inflation factors (VIF) and graph or tabulation.

The VIF collinearity statistics of SPSS was applied to test the existence of multicollinearity among the variables through specifying of collinearity statistics for each variable. As a rule of thumb, there is no problem of multicollinearity if the coefficient of these statistics less than or equal to 2. Fortunately, the values of the coefficient of these statistics among the variables are less than or equal to 2 for each site. Hence, for the specified variables, multicollinearity was not a problem.

SPSS econometric packages also plots the graphs of standardized residuals against frequency of their occurrences with the normal curves and the Norma p-p plots of observed Cum prob against expected Cum Prob of the dependent variables. Almost, all the variables of plots showed us the normal distribution of the residuals. In other words, the assumption of heteroscadesitciy was rejected and then the assumption of homsecadesticity was accepted.

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DECLARATION

I declare that this thesis is my original work and has not been presented for a degree in any university and all the sources of materials used for the thesis are duly acknowledged.

Name: Nigussie Tefera

Signature: Nigussie

Date: July 11, 2001

Place: Addis Ababa University, Addis Ababa