Session 1

# Objectives, outcomes, and trade-offs associated with alternative fertilizer promotion programs

## African Agricultural Markets Programme (AAMP)

Common Market for Eastern and Southern Africa

Fertilizer Training Workshop

Livingstone, Zambia

18-19 June 2009

## Overview of Fertilizer Training Workshop: Sessions

- Session 1: *Objectives, outcomes, and trade-offs associated with alternative fertilizer promotion programmes.*
- *Session 2: What determines the cost of fertilizer at the farm gate? Cost build-up analysis (Bumb, IFDC)*
- *Session 3: Fertilizer profitability analysis (Rashid and Jayne, IFPRI/MSU)*
- *Session 4: Experiences and lessons learned with alternative fertilizer promotion efforts (Minot, Jayne)*
- *Session 5: Fertilizer Policy Toolkit – an interactive policy tool (*Kopicki, World Bank)

## Session 1: Main points to cover

- Objectives of fertilizer promotion programmes?
- Stages in the fertilizer delivery system
- Under what conditions will farmers purchase fertilizer?
- Under what conditions will private traders stock fertilizer for sale?
- Concept of displacement
- Complementary public sector activities to support fertilizer use

## Issue 1: Objectives of fertilizer promotion programmes

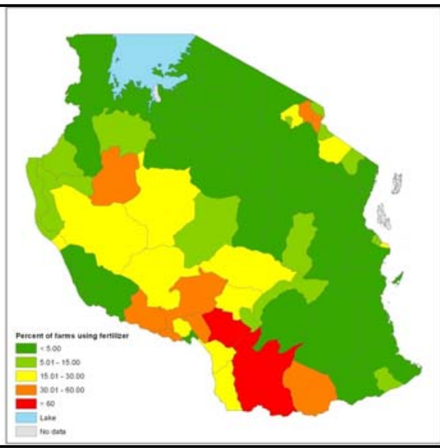
- Improve high-yielding varieties – productivity growth
- To promote private sector
- Food and nutrition security
- Poverty reduction

## Issue 2: Stages in the fertilizer delivery system

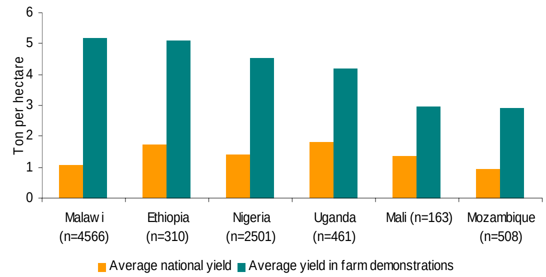
- Retailers
- Wholesales
- Importers
- Shippers
- Producers

## Issue 3: Under what conditions will farmers purchase fertilizer?

- Distance – transport costs
- Extension services to increase farmer know-how – management ability
- Subsidies in remote areas to reduce costs
- Agro-ecological conditions
- Financial -- ability to purchase
- Access to profitable output markets
- Availability and use of improved seed
- Availability of fertilizer
- Crop mix – some crops don't respond to fertilizer




## Gap between actual and potential maize yields

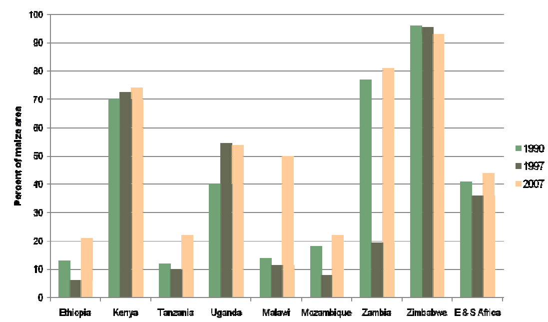



Actuals from survey data; potential for SG-2000 on-farm demonstrations

## Factors limiting fertilizer use:

1. **Lack of profitabilty:** usually due to
   - Weak physical infrastructure
   - Downside crop price risk → risky
   - Unavailability of improved seed
   - Inefficient farm management, agronomic practices
2. **Lack of credit:** inability to buy fertilizer
3. **Market failure:** Fertilizer may be profitable and there is effective demand, but retailers are not making fertilizer available
4. **Lack of information:** about seeds to use, prices, payoffs to fertilizer use

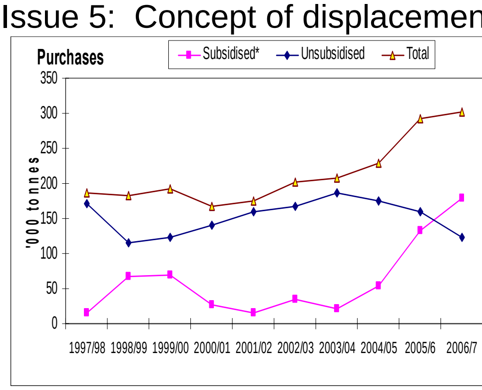
## Adoption of improved seed varieties




## Issue 4: Under what conditions will traders stock fertilizer for sale?

- The agro-dealer may not have the information to know what kind of fertilizer to stock, and to know what the farmer needs, proper application rates, etc.

## Issue 5: Concept of displacement



Issue 6: Complementary public sector actions to support fertilizer use

How to close the gap between productivity-maximizing yields and existing yields?

1. Profitability
2. Access to credit
3. How to ensure private sector response

## Profitability of using fertilizer

$$\frac{\textbf{Farm-gate Maize Price}}{\textbf{Farm-gate Fertilizer Price}} * \frac{\boldsymbol{\Delta}\textbf{kg maize}}{\boldsymbol{\Delta}\textbf{kg fert}}$$

## Holistic Approach

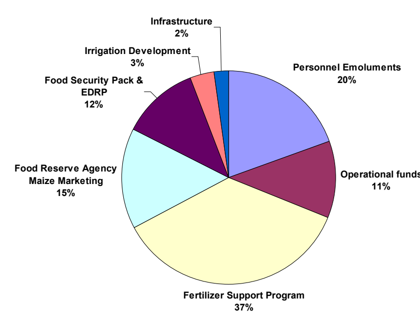
1. Public investments to <u>raise profitability</u> of fertilizer use:
   - **Infrastructure:** port, road, rail
   - **Crop science:** improved seed and agronomic management
   - **Extension:** know-how to improve efficiency of labor and input use
   - ***Crop marketing*:** reduce downside price risk
   - **Regional trade:** export bans reduce farm prices, depress incentives to adopt fertilizer

## IFPRI review of rate of return studies:

| | Returns |
|---|---|
| Input subsidies | < 0 to 12% |
| Public Investments in | |
| - research & extension | 35% to 70% |
| - roads | 20% to 30% |
| - education | 15% to 25% |
| - communications | 10% to 15% |
| - irrigation | 10% to 15% |

**If we believe these findings, they have major implications**

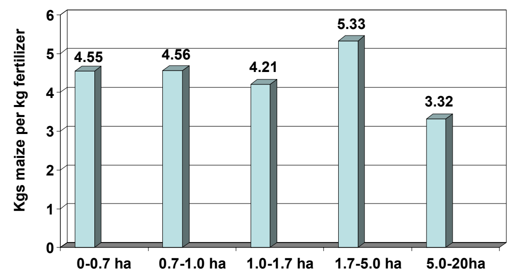
Budget allocation to Agricultural Sector in Zambia: ZMK465 million in 2005



## Holistic Approach

2. Address credit issues:
   - Implement targeted subsidy programs in which credit or fertilizer is targeted to the poor, who lack ability to purchase inputs
   - But can the poor really use fertilizer as productively as bigger farmers?

## Maize-fertilizer response rates in Zambia by farm size




Source: Crop Forecast Surveys, CSO

*Grain Market Research Project*

# AGRICULTURAL MARKET PERFORMANCE AND DETERMINANTS OF FERTILIZER USE IN ETHIOPIA

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# Agricultural Market Performance and Determinants of Fertilizer Use in Ethiopia

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# 1. INTRODUCTION

Ethiopia has a population of 55 million (1995), the second largest in sub-Saharan Africa. Growing at a rate of 3 percent per annum, the population is expected to double by the year 2010. The level of urbanization is very low, with only 15 percent living in the urban areas. Close to 50 percent of the total population is reported to be under the age of 14 years, implying a very high dependency ratio.

One immediate effect of the population pressure has been diminishing farm size. In 1995/96, about 63 percent of farming households had less than 1 ha of holdings. Fewer than 1 percent of the farmers owned holdings greater than 5 ha and these were likely to be concentrated in the sparsely populated areas with low agricultural potential (CSA, 1996).

With declining farm size, it becomes increasingly difficult to practice traditional soil-fertility restoring techniques (e.g.fallowing and crop rotation) and maintain households' livelihoods from the land. As noted by Boserup and others, rising population density typically causes a transition from fallow-based systems to permanent cultivation. To maintain yields under these conditions, farmers must add supplementary nutrients using increased quantities of organic and chemical fertilizers. Although the use of fertilizer has increased in Ethiopia in recent years, there is ample evidence that most farmers are not adequately compensating for the loss of soil nutrients caused by more intensive cultivation (Mulat, 1996). In many densely populated areas, farmers plant cereal after cereal to meet their subsistence requirements with little or no application of commercial or organic fertilizer. Although the benefit of chemical fertilizer is known by many, only 31% of the farmers in the country used commercial fertilizer in 1995/96 and just 37% of the cultivated area was treated (CSA, 1996). The picture for organic fertilizers is not any more encouraging. Because of fuelwood scarcity, rural households have been forced to divert animal dung from its traditional role as soil nutrient to direct burning for fuel (Senait, 1997). Crop residues and other by-products are used as animal feed, thus aggravating soil degradation and erosion. Uncontrolled deforestation of the natural vegetation cover, high stocking rate, farming practices with little concern for conservation and poor soil management practices have resulted in low and stagnating yields. Coupled with diminishing farm size, the generally stagnant yields have resulted in sharply declining labor productivity (measured by output per agricultural laborer) and poverty[1].

Agricultural development strategies need to effectively reduce the key constraints to growth. Hayami and Ruttan (1984), for instance, noted that the constraints imposed on agricultural development by an inelastic supply of land can be offset by advances in biological technology, while the constraints imposed by an inelastic supply of labor can be offset by advances in mechanical technology. The ability of a country to achieve growth in agricultural productivity and output depends on its ability to make an efficient choice among alternative paths of technical change. In this regard, declining farm size will not necessarily translate into

[1] See for instance, Yibeltal Gebeyehu, 'Population Pressure, Agricultural Land Fragmentation and Land Use: A Case Study of Dale and Shashemene Weredas, Southern Ethiopia. In Dejene Aredo and Mulat Demeke (eds.), *Ethiopian Agriculture: Problems of Transformation*, proceedings of the Fourth Annual Conference on the Ethiopian Economy, Addis Ababa, 1995.

underemployment and poverty in Ethiopia if a transition is made to intensive land use and/or rapid growth in non-farm employment.

Recognizing the seriousness of the soil fertility problems in Ethiopia and the necessity of improving agricultural productivity and food security if general economic growth is to occur, the present Federal Democratic Republic of Ethiopia initiated a broad based Agricultural Development-led Industrialization (ADLI) strategy in the early 1990s. The strategy concentrates on accelerating growth through focusing on the supply of fertilizers, improved seeds and other inputs. Although food production began to improve after 1994, the country is still facing widespread chronic and transitory food insecurity in some areas of the country.

The objective of this research is to examine how the fertilizer sector in general, and farmers' demand for fertilizer in particular, has evolved since the introduction of fertilizer sector reforms in Ethiopia. There is much debate in the agricultural development literature about whether fertilizer use in Africa is constrained primarily by poor input distribution systems, by farmers' lack of knowledge concerning the benefits and correct use of fertilizer, or by lack of effective demand because the product is simply not profitable enough. In our research we have looked at each of these issues in an effort to understand the relative importance of the different constraints and how well current policies are addressing the problems. In doing this, we attempt to identify additional policy measures needed to sustain expanded use of fertilizer and thus enhance food security in Ethiopia.

The data for the study come from three principal sources:

(1) the Agricultural Survey carried out by the Central Statistical Office (CSA) for the year 1995/96 season;

(2)

(3) the Food Security Survey (1995/96) conducted by the CSA in collaboration with the Grain Market Research Project of the Ministry of Economic Development and Cooperation; and

(4) fertilizer trials conducted from 1989 through 1991 by the Ministry of Agriculture (MOA) and the National Fertilizer and Inputs Unit (NFIU). In addition, observations from several field visits were used to corroborate findings obtained from data analyses.

Production functions have been used to analyze profitability and identify profit maximizing fertilizer application rates. Regression models using wereda-level data have been estimated to identify the most important factors influencing fertilizer adoption and total quantity used.

After presenting a brief review of aggregate national statistics on farm size, yields, and fertilizer use patterns, we examine recent progress in the development of fertilizer and agricultural credit markets (the supply side of the subsector). We then turn to a review of recent evidence on fertilizer profitability and other factors such as household characteristics, agroecological conditions, and choice of crop mix that shape farmer's demand for fertilizer. In Section 5, we present the results of an econometric selection model to identify factors determining whether fertilizer is used in a given wereda as well as factors determining the intensity of fertilizer use in weredas where fertilizer has been adopted. We conclude with a discussion of implications for the design of future agricultural programs and policies.

## 2. RECENT PATTERNS IN ETHIOPIAN AGRICULTURE

As mentioned in the introduction, most analysts agree that population growth is decreasing farm size per capita and compromising the traditional system of regenerating soil fertility through use of fallows. Table 1 presents the distribution of farm size for the 1995/96 cropping season. Almost 40% of farms are less than 0.5 hectares and about 60% are less than one hectare. Any farm more than 5 hectare is in the largest 1% of farms. If farm families are to feed themselves and produce a marketable surplus with less land per capita, they need to adopt farming techniques on a sustainable basis in order to increase yields per hectare.

**Table 1. Distribution of Holding Size**

| Landholding (ha) | Number of Households | Cumulative (%) |
|---|---|---|
| under 0.1 | 634560 | 7.45 |
| 0.10 - 0.50 | 2556940 | 37.47 |
| 0.51 - 1.00 | 2166350 | 62.91 |
| 1.01 - 2.00 | 2029560 | 86.74 |
| 2.01 - 5.00 | 1060840 | 99.2 |
| 5.01 - 10.00 | 62280 | 99.93 |
| 10+ | 5940 | 100 |

Source: CSA, Agricultural Sample Survey 1995/96, Vol. IV, Report on Crop Land Utilization, Bulletin No. 152, 1996.

Unfortunately, yields have not been increasing to compensate for the reduction in area cultivated per capita and the smaller farm sizes. Table 2 presents the trends in average yields since 1980 for seven of Ethiopia's principal food crops. One notes a fair amount of inter-annual fluctuation in yields, due primarily to climatic variability. There is no evidence of the type of steady growth in yields per hectare needed to feed a national population that is growing at 3% per year, although there is some evidence of a recovery in yields during the early 1990s. A simple linear regression of yields(1980 to 1995) as a function of time showed that the coefficient (of the time variable) was insignificant, suggesting stagnant yields for all the major crops but wheat, which registered a positive growth rate. Even maize, which has been the engine of agricultural growth in much of Eastern and Southern Africa due to breakthroughs in variety development, does not exhibit yield levels in the 1990s that outpace what was realized in the early 1980s.

**Table 2. Yield of Major Crops in Quintal per Hectare**

| YEAR | Cereals | Teff | Barley | Wheat | Maize | Sorghum | Pulses | Oil Seeds |
|---|---|---|---|---|---|---|---|---|
| 1980 | 11.82 | 9.63 | 13.20 | 11.04 | 12.37 | 14.58 | 11.59 | 5.11 |
| 1981 | 11.59 | 8.14 | 11.92 | 10.03 | 17.90 | 14.63 | 10.49 | 3.65 |
| 1982 | 13.41 | 9.81 | 13.14 | 12.64 | 19.90 | 15.37 | 12.27 | 4.78 |
| 1983 | 11.62 | 8.28 | 10.21 | 10.40 | 18.52 | 13.22 | 9.71 | 3.84 |
| 1984 | 8.68 | 6.76 | 10.42 | 9.88 | 11.32 | 6.70 | 6.77 | 3.66 |
| 1985 | 9.43 | 7.41 | 9.83 | 9.58 | 11.25 | 10.68 | 6.39 | 3.43 |
| 1986 | 11.59 | 8.09 | 11.20 | 11.09 | 16.53 | 12.85 | 9.15 | 3.88 |
| 1987 | 12.08 | 8.17 | 12.15 | 11.50 | 19.05 | 11.53 | 7.63 | 4.11 |
| 1988 | 12.28 | 8.84 | 11.43 | 12.26 | 18.45 | 13.87 | 9.07 | 3.54 |
| 1989 | 13.14 | 8.59 | 13.75 | 12.84 | 19.59 | 13.34 | 10.56 | 4.00 |
| 1990 | 13.65 | 14.29 | 12.92 | 14.35 | 12.75 | 13.71 | 14.22 | 12.89 |
| 1991 | 10.27 | 8.70 | 1.25 | 13.83 | 16.44 | 13.01 | 8.91 | 4.18 |
| 1992 | 13.43 | 10.04 | 13.20 | 15.93 | 18.53 | 14.84 | 8.23 | 3.34 |
| 1993 | 12.94 | 9.05 | 15.15 | 13.74 | 16.54 | 15.80 | 7.38 | 3.80 |
| 1994 | 10.71 | 7.04 | 9.64 | 13.31 | 15.15 | 12.66 | 8.82 | 3.43 |
| 1995 | 9.84 | 8.36 | 10.57 | 12.20 | 19.83 | 0.00 | 9.78 | 4.99 |

Source: Dejene Aredo, The Determinants of Cropping Pattern and Agricultural Productivity in Ethiopia 1980 - 1995, Department of Economics, AAU (mimeo), 1997.

Given the average farm size of about 1 hectare for a family with approximately 5 persons, cereal yields in the range shown in Table 2 (800 to 1300 kilograms per hectare, with the exception of maize that goes as high as 2000 kgs/ha.) are, at best, barely adequate for feeding household members.[2] Given current technology and yield levels, the 60% of households that cultivate less than one hectare of land cannot be expected to generate much cash income from farming after meeting their own consumption requirements.

Chemical fertilizers are recognized as one of the key means for increasing yields per hectare. Table 3 illustrates patterns of fertilizer use during the 1995/96 meher cropping season. Most fertilizer is used in four regions: Oromiya, Amhara, Southern, and Tigray. Average national doses are about 35 kilograms/ha when users and nonusers are considered, while average doses applied by users only are 95 kilograms/ha. These application rates are relatively high compared to past experience in Ethiopia, but they are far below the nutrient needs of the heavily-cropped Ethiopian soils which have been under cultivation for centuries.

[2] Given grain requirement of 156 kg/person per year (225 kgs total as recommended by the Ethiopian Medical Association * 0.7 as 70% of the Ethiopian diet is in the form of grains), a family of 5 household members requires approximately 790 kg of grains per year to meet minimum caloric requirements. Since part of the harvest may need to be sold to meet other needs (e.g. clothing, health care, education, taxes), the average yields reported in Table 2 suggest that many small farms do not meet minimum subsistence needs from their agricultural production.

**Table 3. Characteristics of Fertilizer Use on Cereals (1995/96 Meher Season)**

| Region/crop | Area cultivated (000 ha) | Area fertilized (percent) | Dose (kg per hectare) Across all farms | Dose (kg per hectare) Users only |
|---|---|---|---|---|
| Tigray | 437 | 21 | 11 | 51 |
| Teff | 88 | 22 | 19 | 87 |
| Barley | 87 | 24 | 17 | 69 |
| Wheat | 85 | 19 | 17 | 88 |
| Maize | 45 | 49 | 1 | 2 |
| Sorghum | 96 | 9 | - | - |
| Amhara | 2,380 | 30 | 22 | 75 |
| Teff | 882 | 41 | 33 | 81 |
| Barley | 296 | 16 | 10 | 66 |
| Wheat | 259 | 25 | 28 | 112 |
| Maize | 290 | 51 | 26 | 5 |
| Sorghum | 472 | 1 | - | - |
| Oromiya | 3,034 | 47 | 47 | 100 |
| Teff | 941 | 66 | 81 | 123 |
| Barley | 385 | 41 | 32 | 78 |
| Wheat | 470 | 68 | 83 | 121 |
| Maize | 700 | 33 | 16 | 50 |
| Sorghum | 452 | 11 | 7 | 58 |
| Southern | 609 | 38 | 47 | 126 |
| Teff | 160 | 52 | 62 | 120 |
| Barley | 52 | 35 | 45 | 131 |
| Wheat | 58 | 83 | 41 | 155 |
| Maize | 195 | 33 | 6 | 123 |
| Sorghum | 140 | - | | - |
| National | 6,652 | 37 | 35 | 95 |
| Teff | 2,097 | 52 | 57 | 110 |
| Barley | 826 | 29 | 23 | 79 |
| Wheat | 882 | 51 | 63 | 123 |
| Maize | 1,281 | 36 | 21 | 58 |
| Sorghum | 1,252 | 7 | 4 | 52 |

Source: CSA, Agricultural Practices, Bulletin No. 152, 1996

In the past, attempts to increase crop yields included the comprehensive and minimum package projects initiated in the late 1960s and 1970s and the Peasant Agricultural Development Project (PADEP) launched in the 1980s. The basic aim was to promote agricultural development by concentrating inputs, credit and marketing services and building infrastructure in geographically delimited areas. Integrated rural development projects were considered as the most effective tools to bring about maximum impact within a short period of time.

Within the framework of the ADLI strategy, a new system of agricultural extension, known as the Participatory Demonstration and Training Extension System (PADETES), was launched in 1994/95. The system tries to merge the extension management principles of the Training and Visit (T & V) system with the technology diffusion experience of the SG 2000 program.[3] The major elements of the extension package are fertilizer, improved seeds, pesticides and better cultural practices for the main cereal crops (teff, wheat, maize, barley, sorghum and millet). In addition, a series of measures have been introduced since November 1991, progressively liberalizing fertilizer supply and marketing. Very recently (February 1997), fertilizer subsidies were removed and retail prices deregulated.

While fertilizer use in Ethiopia has increased notably since 1990, agricultural intensification in general and fertilizer consumption in particular, are not progressing as rapidly as desired. The remainder of the paper examines the diverse factors that constrain fertilizer adoption and application rates, in view of helping policy makers design sustainable programs that promote agricultural intensification through the use of chemical fertilizers.

[3] The centrepiece of the SG 2000 program is half-hectare demonstration plots managed by participating farmers who use a complete package of improved seeds, improved management practices, and fertilizer doses and seed rates as recommended by the National Fertilizer Input Unit of the Ministry of Agriculture.

# 3. MARKET DEVELOPMENT AND THE SUPPLY OF CREDIT

Fertilizer demand is heavily influenced by the market structure and credit availability. The recent economic reform has liberalized the fertilizer market and allowed the participation of the private sector with the aim of improving distribution and consumption. Progress has been made to improve the supply of fertilizer and credit, but our review of the subsector suggests that more can be done to increase the efficiency of the credit program. A particular concern is evidence that the manner in which credit is allocated to farmers' organizations exacerbates problems of oversupply by private sector importers and distributors and also discourages competition among fertilizer retailers at the local level. The latest developments concerning market structure and credit are briefly reviewed below in order to throw light on the implications of the ongoing reform for fertilizer demand and profitability.

## 3.1. The Structure of the Fertilizer Market

Up until 1992, the fertilizer market was entirely controlled by the state owned parastatal named the Agricultural Input Supply Corporation (AISCO), now renamed as the Agricultural Input Supply Enterprise (AISE). Consistent with the new economic policy, the Government designed the New Marketing System (NMS) for fertilizer in 1992 with the main objective of liberalizing the fertilizer market and creating a multi-channel distribution system. The liberalization permitted the private sector to engage in the importation and distribution of fertilizer, hence ending the monopoly power of AISCO[4]/AISE. AISE started by appointing its own wholesalers and retailers.[5] Only two firms have joined the market for fertilizer import and distribution since the 1992 reform. In 1993, the Ethiopian Amalgameted Limited (EAL) became the first private company to import and set up its own fertilizer supply network. Its market share in the total import increased to 27.9% in 1996 (Table 4).[6] The second firm, owned by the Amhara Regional Government, started operation in 1994 under the name, Ambassel Trading House Private Limited Company. It is mainly a wholesale and distribution agent of AISE and collects its supplies from Assab. In 1996, the company was appointed as the sole distributor and wholesaler of AISE in the Amhara region. It was also allocated foreign exchange by the Government to import fertilizer in 1996. EAL and Ambassel together accounted for 35.1% of total fertilizer imports in 1996 (Table 4).

[4] AISCO was established in 1985. Between 1978 and 1984, the Agricultural Marketing Corporation (AMC), State-owned parastatal, was the sole importer and distributor of fertilizers.

[5] In 1992, 7 wholesalers and 114 private retailers were registered in some parts of Shewa, Gojam, Arsi and Hararghe.

[6] The firm did not import in 1997 because of large unsold stock from the previous year. Only AISCO imported fertilizer in 1997 (Table 4).

**Table 4. Fertilizer Import by Firm**.

| | 1995 | | 1996 | | 1997 | |
|---|---|---|---|---|---|---|
| | Imports | Share (%) | Imports | Share (%) | Imports | Share (%) |
| AISE | 232219 | 81 | 219574 | 64.8 | 160000 | 100 |
| EAL | 55400 | 19 | 94669 | 27.9 | 0 | 0 |
| Ambassel | - | - | 24337 | 7.2 | 0 | 0 |
| Total | 287619 | 100 | 338780 | 100 | 160000 | 0 |

Source: National Fertilizer Industry Agency (1997)

Each of the three importers/distributors has its own dealer network. AISE and its network of distributors, wholesalers and retailers covered nearly the whole country. With 1 distributor (Ambassel), 103 wholesalers, 901 retailers and 860 service cooperatives in 1996, AISE's operation is the largest in the country. The network of Amalgameted included 230 direct sales centers, 1,285 private retailers and 550 service cooperatives. Ambassel operated with 94 direct sales centers, 120 private retailers and 385 service cooperatives in 1996. Among the major distributors/wholesalers that joined the market in 1996 and 1997 are Dinsho (owned by the Oromiya Regional Government) and Guna (owned by the Tigray Regional Government).

Consistent with the Government's liberalization policy, a total of 229 AISE's marketing centers have been phased out. The transfer has already been made in the Amhara region, with Ambassel taking over nearly all the centers in the region. In the Oromiya region, most of the AISE's centers in East Shewa, West Shewa, North Shewa and Arsi were taken over by Dinsho in 1996. In other regional states, AISE carries out its operations on its own (direct sales to farmers) and/or through its private wholesale and retail agents.

Access to fertilizer is thought to have improved as a result of the input market liberalization. However, the full benefit the reform has yet to be realized because of various limitations in the marketing system. There are at least four major problems associated with the existing structure of the fertilizer market which seem to have affected demand directly or indirectly:

(i) retail markets are poorly developed (most sales to farmers going thru a limited number of retail outlets run directly by the major distributors/wholesalers), hence many farmers do not have easy access to a retail outlet;

(ii) system of credit disbursement to farmers that discourages competition and leads to market concentration and uncertainty for potential new entrants in fertilizer distribution;

(iii) principal-agent relationship; and

(iv) regulation of prices.

First, limited participation by small-scale wholesalers and retailers has made the fertilizer market uncompetitive and inaccessible. For instance, about 80% of AISE's sales in 1997 were through distributors/wholesalers (mainly Ambassel, Dinsho and Guna). The share going to retailers, individual farmers and the non-peasant sector was 15, 2 and 3%, respectively (AISE, 1997). In the case of Ambassel, direct sales to farmers and service cooperatives accounted for 52 and 39% of the total sales, respectively, in 1997. Small wholesalers accounted for only 3% of the total sales of the company. The remaining (5%) was sold to state farms. In 1997, most sales of EAL were directed to the large distributors such as Ambassel, Dinsho and Guna which also carried out the retailing operations.

Retailing by the large firms implies that sales or retail outlets are few and concentrated in the towns and along the major roads, and the terms and conditions of sales are not sufficiently flexible. It is often expensive and sometimes unmanageable for the large distributors to maintain several sales centers within a given wereda and provide sales service throughout the year. Often the companies do not have the capacity to sell fertilizer on flexible terms (e.g on the basis of informal credit arrangements or exchange for grain). A more efficient, flexible and a wider distribution of fertilizer can only be ensured if local traders are allowed to participate fully. Among the major reasons for the lower rate of participation were the manner in which credit is allocated (see section 3.2 below), the removal of subsidy and the unattractive wholesale price fixed by the government, and limited access to credit. For most of the small private wholesalers and retailers, adding adequate retail margin on the wholesale price meant making fertilizer even more expensive or limited demand for the input. The large distributors/wholesalers sold at the wholesale price direct to the service cooperatives and farmers group. The latter sold to their members at the wholesale price plus some transport cost.[7] Even before the removal of subsidies, the participation of small dealers was minimal because most of them were unable to raise sufficient working capital to engage in fertilizer trade. Access to credit is constrained by the heavy collateral requirement and the absence of banking services in most weredas.

Second, excess supply was a serious constraint in 1996 and 1997 and the problem was more serious for some than for the other firms. In 1996, for instance, AISCO and Ambassel sold 72.9 and 75.3% of their total supply, respectively. The performance of both firms was well above EAL which was able to sell only 29.2% of its supply.[8]

In 1997, AISE sold only 46% of its total supply. The performance of EAL improved significantly over the previous year, with 69% of stocks sold. EAL sold fertilizer to other distributors such as Ambassel and Dinsho at below retail-price levels to get rid of its unsold

[7] The amount charged by the service cooperatives and farmer groups for the service provided (buying fertilizer from distributors) varies from place to place. But the cost of transport and perdiems for the delegates who make the purchase is included in the charge. For instance, farmers paid upto 3 birr/quintal for transport and perdiems in the district of Ada (Debre Zeit) in 1997.

[8] Overall, only 59.4% of the total amount of fertilizer made available by all firms was actually sold in 1996, with about 164,932 tons of fertilizer left unsold.

stock from the previous year. Ambassel and Dinsho sold over 87% of the total fertilizer that they handled.[9] Tables 5 and 6 shows the performance of sales for each importer/distributor.

**Table 5. Sales Performance by Distributor (1996 and 1997)**

| | Total Available[a] (tons) | | | Total sales (tons) | | | % sold | | |
|---|---|---|---|---|---|---|---|---|---|
| Importer | DAP | Urea | Total | DAP | Urea | Total | DAP | Urea | Total |
| 1996 | | | | | | | | | |
| AISCO | 153537 | 46994 | 200531 | 120155 | 26045 | 146200 | 78 | 55 | 73 |
| EAL | 95669 | 33785 | 129454 | 33553 | 4212 | 37765 | 35 | 12 | 29 |
| Ambassel[b] | 61799 | 14797 | 76596 | 46543 | 11141 | 57684 | 75 | 75 | 75 |
| Total | 311005 | 95576 | 406581 | 200251 | 41398 | 241649[c] | 64 | 43 | 59 |
| 1997 | | | | | | | | | |
| AISE | 96165 | 57700 | 153865 | 57613 | 13050 | 70663 | 60 | 23 | 46 |
| EAL | 42946 | 23694 | 66640 | 36195 | 9512 | 45707 | 84 | 40 | 69 |
| Ambassel | 50169 | 13657 | 63826 | 45457 | 12809 | 58266 | 91 | 94 | 91 |
| Dinsho | 22301 | 9684 | 31985 | 20387 | 7613 | 28000 | 91 | 78 | 87 |
| Guna | 2187 | 1726 | 3913 | 2002 | 1656 | 3658 | 92 | 96 | 93 |
| Total | 213769 | 106461 | 320229 | 161654 | 44640 | 206294 | 76 | 42 | 64 |

Source: NFIA data files.
Notes: (a) Total available includes import plus carry-over stock from the previous year
(b) Includes imports of AISCO sold to Ambassel
(c) This amount is different from the amount reported in 1997 by Tibebu Haile (see Annex I).

[9] Overall, unsold stock amounted to 113,936 tons in 1997 and fertilizer consumption declined by 18.5% over the previous year (Annex I).

**Table 6. 1997 Fertilizer Sales by Region and Distributor (to August 31, 1997)**

| Region | DAP sales (total tons per region and percent of sales by each distributor) | | | | | | Urea sales (total tons per region and percent of sales by each distributor) | | | | | | DAP + Urea sales (total tons per region and percent of sales by each distributor) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TOTAL | AIS | EAL | AMB | DIN | GUN | TOTAL | AIS | EAL | AMB | DIN | GUN | TOTAL | AIS | EAL | AMB | DIN | GUN |
| Tigray | 7046 | 29% | 43% | - | - | 28% | 5388 | 27% | 42% | | | 31% | 12434 | 28% | 42% | - | - | 29% |
| Amhara | 43980 | - | 1% | 99% | - | - | 11525 | | <1% | 99% | | | 55505 | - | <1% | 99% | - | - |
| Oromiya | 72931 | 37% | 35% | - | 28% | - | 17863 | | | | 34% | 23% | 90794 | 37% | 33% | - | 31% | - |
| Somali | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Benishangul G. | 70 | 100% | - | - | - | - | 75 | 100% | | | | | 145 | 100% | - | - | - | - |
| SNNPR | 27786 | 83% | 17% | - | - | - | 2905 | 95% | 5% | | | | 30691 | 84% | 16% | - | - | - |
| Gambella | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Harari | 434 | - | 100% | - | - | - | - | - | - | - | - | - | 434 | - | 100% | - | - | - |
| AddisAbeba | 1751 | - | 100% | - | - | - | 794 | <1% | 99% | | | | 2545 | <1% | 99% | - | - | - |
| DireDawa | 502 | - | 100% | - | - | - | 578 | | 100% | | | | 1080 | - | 100% | | | |
| Other regions | 7154 | 73% | | 26% | | | 5512 | 48% | 29% | 23% | | | 12666 | 62% | 13% | 25% | - | - |
| G.Total | 161654 | 36% | 22% | 28% | 13% | 1% | 44640 | 29% | 21% | 29% | 17% | 4% | 206294 | 34% | 22% | 28% | 14% | 2% |

Note 1. EAL's distribution in Tigray is assumed to be sold as there is no information obtained regarding the actual sales.
2. Sales figures refer to sales to farmers, private commercial farms and research centers, etc. It doesn't include sales to other importing companies or distributors.

The firms with huge carry-over stocks incur considerable additional costs in the form of storage and interest charges. The extra cost may be covered by the firms themselves or passed on to the farmers. In any case, failure to sell the available supply implies serious uncertainty, besides the financial problems. Sales uncertainty can also impede free entry into the fertilizer market and constrain investment in market infrastructure.

Part of the carry-over stocks for all firms can be attributed to incorrect demand forecasts. EAL, however, claims that the exceptionally large size of their 1996 carry-over stocks is due to an uneven playing field caused, in large part, by the structure of the credit program. EAL claims, for example, that all credit sales in the Amhara region are directed to Ambassel. This has permitted Ambassel to progressively dominate the Amhara market so that by 1997 the firm supplied 99% of the total fertilizer sold to farmers, state farms, private commercial farms, and research centres in the region. If EAL's claims are correct, this raises serious questions about the extent to which current fertilizer policy is fostering the development of local monopolies and discouraging private investment in the fertilizer sector.

The fertilizer market in SNNPR was not dominated by one distributor as much as in Amhara, but nevertheless one firm, AISE, accounted for 84% of the total sales in 1997. The remaining 16% was supplied by EAL.

More competition was evident in the Oromiya region, but the competition did not reach all the way down to the wereda level. Three companies supplied Oromiya farmers in 1997, namely AISE (37% of the market), EAL (33%) and Dinsho (31%). Although the market shares are similar, the firms usually operate in different localities so there is no effective competition at the local level. The local authorities direct all credit sales to Dinsho in weredas where the company operates. Dinsho faces no threat of competition from AISE as the former is largely recognized as wholesale agent of the latter (except in rare cases like dumping by EAL in 1997). Credit sales by AISE are approved in areas not covered by Dinsho or Ambassel. Hence, fertilizer buyers in a given wereda do not have the opportunity of choosing among dealers in the region.

Third, fertilizer distribution is characterized by the principal-agent relationship between importers and wholesalers/retailers. Wholesalers and retailers are not in a position to call on several suppliers and obtain the best possible deal. They operate as commission agents of the importers and are therefore unable to establish themselves as fully independent and competing operators. If the plan to introduce licensing of fertilizer dealers/agents by the government becomes effective, dealers will have the opportunity to buy the input from suppliers of their choice. This will widen the distribution network and attract new entrants into the market.

Finally, fertilizer demand is also affected by regulated prices. Although retail prices have been deregulated (since February 1997), the wholesale price is still fixed by the government. Although the wholesale price for 1997 was announced earlier than the previous years, dealers took a long time to work out the implications for retail prices for the various regions or sites. As a result, fertilizer sales started after the belg season was over in many places. Moreover, price fixation by the government implies that sales of fertilizer do not start until the price for the year is announced by the government. For many farmers, sales start long after they have sold their grain, not when their cash constraint is less binding. The market is expected to improve with the deregulation of the wholesale fertilizer prices by December 31, 1997.

### 3.2. Credit

Fertilizer sales are largely financed through credit in Ethiopia. It is estimated that close to 80% of annual fertilizer purchases are covered by credit from the banks.[10] Historically, fertilizer demand has gone up and down following increases and decreases in the supply of credit.[11]

Because of massive default, the Agricultural and Industrial Development Bank of Ethiopia (AIDB) sharply reduced its supply of fertilizer loans in the early 1990s.[12] The loss was absorbed by the state and the bank was renamed as Development Bank of Ethiopia (DBE). DBE was granted a fresh start in 1992. The Transitional Government of Ethiopia (TGE) also revised the 1988 Rural Credit Policy of the National Bank of Ethiopia (NBE), which made input loans a close preserve of AIDB.[13] In 1994, the Commercial Bank of Ethiopia (CBE), with 150 branches, became involved in the extension of agricultural credit along with the DBE (35 branches) and the former AIDB. Loan recovery improved after the disastrous record of the early 1990s. CBE, for instance, reported a recovery rate of 92% and 83% in 1995/96 and 1996/97, respectively. DBE also reported a recovery of 95% and 87% during the same period (Table 7).

[10] For instance, 2,098,830 qt of DAP and 432,690 qt of urea were sold in 1996. Assuming farmers pay some 25% of the total cost in the form of down-payment, the financial requirement for the transaction can be estimated as 376,482,825 birr. The banks extended 298,965,000 or 79.4% of the requirement in the same year.

[11] See for instance, KUAWAB/DSA, Fertilizer Marketing Survey, Vol. 1, USAID/Ethiopia, Addis Ababa, April 1995.

[12] Poor credit recovery (54% in 1990, 37% in 1991 and 15% in 1992) resulted in outstanding loans of about 140 million birr. Information on fertilizer disbursement by AIDB and CBE is contained in Annex II.

[13] The financial sector reform raised interest rates from 6% in 1992 to 11-12% in 1993, 14-15% in 1994, and 15-16% in 1995 and 1996. The NBE directive of 1994 (NBE/INT3/94) allowed the banking sector to set its own lending rates, but fixed the maximum at 15%.

**Table 7. Loan Recovery by Region ('000)**

| Region | 1995/96 Disbursed. | Collected | Outstanding | Rec. Rate | 1996/97 Disbursed. | Collected | Outstanding | Rec. Rate |
|---|---|---|---|---|---|---|---|---|
| **DBE** | **56869** | **56708** | **3267** | **95** | **130364** | **124329** | **18772** | **87** |
| Tigray | 1252 | 1206 | 216 | 85 | na | na | na | na |
| Oromiya | 28790 | 28956 | 1557 | 95 | 63799 | 58245 | 13203 | 82 |
| Amhara | 25688 | 25332 | 1472 | 95 | 37632 | 39351 | 15891 | 99.9 |
| SNNP | 1138 | 1213 | 23 | 98 | 28917 | 25721 | 5549 | 82 |
| Reg. 14 | - | | | | | | | |
| Reg. 13 | - | | | | 16 | 13 | 4 | 75 |
| **CBE** | **221130** | **222522** | **19694** | **91.8** | **242096** | **214585** | **43295** | **83** |
| Tigray | 2093 | 1826 | 415 | 81.4 | | | | |
| Oromiya | 28559 | 30203 | 1184 | 96 | 179053 | 152505 | 39832 | 79 |
| Amhara | 150228 | 149790 | 14034 | 91.4 | 30250 | 31904 | - | 100 |
| SNNP | 36870 | 37035 | 3972 | 90.3 | 29226 | 27765 | 2295 | 92 |
| Reg. 14 | 3380 | 3668 | 90 | 97.6 | 3568 | 2411 | 1168 | 67 |
| Reg. 13 | | | | | | | | |

Source: DBE and CBE records.

*3.2.1. Fertilizer Loan Administration*

The improvement in loan recovery over the last two years was largely due to the administrative measures taken by the regional authorities to enforce repayment. Farmers with overdue loans are threatened with fines and imprisonment to enforce repayment. The power of the local governments was further consolidated when a new credit system was introduced in 1996/97. The responsibility of credit disbursement and collection was transferred from the banks to the regional governments. The regional governments estimate their fertilizer credit requirements and sign a loan agreement with the banks. The regional councils in turn advance the money to service cooperatives and farmer groups. However, different procedures have been applied in processing fertilizer loan by the regions.[14]

In the Amhara and Southern regions, the processing and administration of credit is the sole responsibility of the regional governments. The regional states borrow the input credit

[14] The only exception is in Tigray, where the largest part of fertilizer credit, estimated at about 16 million birr per annum, is met through the funds made available by the Relief Society of Tigray (REST). The credit is processed through REST's Savings and Credit Stations. The terms of credit included 10 to 25% down-payment and the market (bank) lending interest rate is charged on the balance.

directly from the banks and rely on its own administrative machinery and peasant organizations to disburse and collect the loan. To be eligible for credit, a farmer must have repaid all his/her prior loans. The Input Coordination Unit at the peasant association level screens farmers who apply for credit and gives its recommendations in writing to the service cooperatives.[15] The service cooperatives collect similar recommendations from its member peasant associations and submits its application for credit to the Wereda Agriculture Bureau. In the absence of the cooperatives, the peasant associations or other farmers' groups directly submit their request to the Agriculture office. The Bureau does its own screening and then submits aggregated credit requests to the wereda ICU which reviews and decides on each proposal, taking into account the constraints on the amount of redit made available to the wereda by the regional council. Once the request is approved, the wereda administration nominates the supplier of the inputs and advises the wereda Finance Bureau. The Finance Bureau and the cooperatives sign a loan agreement and the cooperatives deposit up to 25% of the fertilizer price (collected from the farmers) as a down-payment. The signing results in the issuance of a delivery order by the Finance office which the cooperatives use to collect their stock from the supplier. The loan, including the accrued interest, is repaid by the regional states as per the agreement concluded.

In Oromiya, the Regional Government concludes the loan agreement on behalf of the borrowers with the banks but the processing and administration of the loan is handled by the banks themselves. The cooperatives or peasant associations apply to the banks for credit with a supporting letter from an authorized wereda official. The banks process the application and issue an input delivery order. Dinsho has been named the designated supplier in the areas where it operates. The Regional Government is responsible for timely loan repayment and, in case of default, is liable as a guarantor.

### *3.2.2. Constraints in the Credit Market*

Although credit repayment has improved under the new arrangement and the volume of credit supply has been increasing in recent years, it appears that the approach suffers from some serious limitations with important implications for fertilizer demand. The system has resulted in direct intervention by the government in the financial market. Credit allocation and collection procedures have deviated from the principles of normal banking operations, leading to distortions, delays in sales and unnecessary strains on the farmers as well as on the administration and extension staff.[16] The allocations of loans are not only bureaucratic but

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[15] In 1995, the Input Coordination Unit (ICU) was established at all levels to coordinate the distribution of all farm inputs. The ICU at the regional, zonal and wereda levels were expected to facilitate loan disbursement and collection by the banks. Representatives from the administration, finance bureau, banks, suppliers and MOA form the committee of the ICU. The committee at the wereda level is chaired by the chief administrator who often plays a key role in the whole process of credit supply and collection.

[16] Other regular development or social activities of the regional bureaus are likely to be adversely affected by the increased work load. Extension and other staff of the agriculture bureau are required to devote a good part on their time to loan disbursement and collection, instead of development activities. Delays in processing loan applications by the local authorities (finance bureaus and others) have also negatively affected timely

also contrary to market principles. For the most part, only firms favored by the authorities are nominated as suppliers: mainly Ambassel in the Amhara region, Dinsho in Oromiya and AISE (together with its wholesale agents) in the Southern. Administrative measures applied to enforce repayment can also be harsh and inconsiderate of the farmers' circumstances. For instance, collection begins immediately after harvest in all areas. All farmers are forced to bring their produce to the market at the same time (to pay their fertilizer debts, taxes, etc.). As a result, supply exceeds demand and prices fall sharply whenever farmers are pressed for repayment. The system does not accommodate the interests of farmers who are willing to incur additional interest costs by delaying crop sales in hopes that prices will rise later in the year.

The penalties for all those who failed to repay immediately after harvest may include the sale of assets (e.g oxen or other animals) by the authorities (together with policemen).[17] Farmers may develop a negative outlook towards fertilizer loans and become more risk-averse. Another commonly practiced measure is to withhold fertilizer credit to cooperatives with defaulting members during the next season. Decisions to withhold credit sales until all members of a given service cooperative have paid their debts are likely to cause unnecessary delays and penalize too many non-defaulting farmers.[18]

Realizing that the marketing and the credit delivery systems are among the major factors contributing to the smooth operation of the market, the government intends to introduce a coupon system. This system would reduce the influence that local officials now have in directing farmers toward particular suppliers. With coupons, farmers will be able to purchase inputs from suppliers of their choice, thereby creating a more competitive distribution network (Tibebu Haile, 1997). The coupon system will not, however, resolve the problems associated with the lack of farmers' organizations capable of handling credit allocation and recovery operations.

The absence of an effective peasant institution for credit delivery is the other major problem associated with the existing credit system in Ethiopia. A typical service cooperative has over

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distribution of fertilizer in parts of the Amhara and Southern region. (See for instance, Itana Ayana, Agricultural Inputs Credit Performance Since 1994 and Plans for 1997, paper presented at the National Fertilizer Workshop, 15 - 18 October, 1996, Addis Ababa). The staff of wereda Finance Bureaus have limited time and experience in loan disbursement and consider the assignment as an additional burden.

[17] Field observations showed that such incidences are not uncommon. For instance, a young farmer in Wonchi (near Wolliso, West Shoa zone of Oromiya region) was approached by the local extension agent to participate in the new extension program during the 1996/97 season. He agreed because he was promised that his yield will double or triple. Unfortunately, his wheat field was attacked by rust and ended up with no harvest. To the dismay of the farmer, the same extension agent, who knows very well about what has happened, told him that all input debts must be paid back. With no other option, the farmer was forced to sell his single ox .

[18] The measure of withholding credit, for instance, resulted in considerable delays in the case of the Oude service cooperative located some 55 km south of Addis Ababa along the highway connecting the capital with Nazreth. Fertilizer sales began 15 to 20 days after the optimal planting time for wheat and teff. The farmers believe that it is not logical to penalize 1,122 farmers (drawn from 6 peasant associations) just because a handful of individuals failed to make the necessary payment.

5 to 6 member peasant associations or over 1000 member households. It is simply too large to provide effective screening of borrowers, identify genuine defaulters, generate reliable demand information, and/or exert any form of peer pressure on members to make timely repayment of debts. At present, local community participation in screening borrowers and filtering genuine defaulters is minimal. The authorities and the leaders of service cooperatives have no objective means of assessing the extent of the crop loss. Weak cooperatives are also the main reason for the government intervention in the credit market and diversion of valuable extension time to administrative affairs. Hence, the effort to restructure service cooperatives into smaller groups needs to be stepped up.

Finally, fertilizer credit is expected to be paid regardless of the harvest. There are no clear provisions to help those requesting even the postponement of repayment for the next season.[19] The sale of critical assets like oxen becomes unavoidable in situations of crop failure. When risk of crop failure is high, credit programs that do not have flexible repayment terms often fail to provide farmers with adequate incentives to use fertilizer. This is a particularly severe problem for resource-poor farmers.

[19] Although loans are occasionally postponed for the next season in situations of serious crop failure, there are no official guidelines regarding the case. Also, granting postponement may not be in the interest of the local authorities when the rate of repayment achieved (at wereda level) is among the major criteria used for evaluating their performance.

## 4. OPTIMUM RATES OF APPLICATION AND FERTILIZER PROFITABILITY

One of the major factors affecting demand for fertilizer is profitability. As shown below the profitability of officially recommended levels of fertilizer use has declined in recent years because of increases in input and decreases in output prices.

### 4.1. Recommendation Rates

Fertilizer use in Ethiopia started with low rates of application. For over two decades, the Ministry of Agriculture (MOA) recommended 100 kg DAP (mainly phosphorous fertilizer) per hectare in most places. The research recommendation that 50 kg of urea (nitrogenous fertilizer) applied along with the 100 kg DAP was largely ignored during this period by the MOA and extension services as well as farmers, except in a few major teff producing areas. This was logical given that larger farm sizes permitted fallowing and crop rotations in which nitrogen fixing pulses and oilseeds were rotated with cereals. Consequently, about 90% of fertilizer imports were in the form of DAP, with urea accounting for only 10%.

Higher application rates were recommended to farmers after the Agricultural Development Department / National Fertilizer and Inputs Unit (ADD/NFIU) conducted four years of fertilizer trials (1988 to 1991). The results of these experiments showed that farmers needed to apply a significantly larger amount of both nitrogen and phosphorous if they wanted to use ‘economically optimum application rates’. The ADD/NFIU researchers defined ‘economically optimum application rates’ as doses that produced a marginal rate of return of 100% (this is approximately the same as saying that the value/cost ratio must equal 2).[20] The optimum rates recommended by ADD/NFIU vary by crop and region but in every case, these ADD/NFIU recommendations exceed those of MOA. In the case of teff, for instance, farmers in Shoa needed to apply 91 kg of urea and 124 kg of DAP per hectare (an increase of 115 kg of fertilizer over previous recommendations). Recommendations for wheat in Shoa increased to 114 kg of urea and 130 kg DAP (a 144 kg increase).

Drawing mainly on these results, the SG 2000 project and the government’s new extension program began recommending that farmers use 100 kg of urea and 100 kg of DAP per hectare for all cereal crops in most areas.

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[20] Referring to a marginal rate of return (MRR) equal to 100% as the ‘economic optimum’ is a bit confusing as most economists would consider the ‘economic optimum’ to be the profit maximizing point, which occurs when the marginal value product divided by the marginal factor cost equals one. It is the terminology, not the decision to use a MRR of 100%, that is problematic; a MRR equal to 100% is commonly used when developing fertilizer recommendations because it results in more conservative levels of fertilizer use, thereby reducing the risk of loss when crop failure occurs. For example, the profit maximizing dose of urea for teff in Shoa using 1992 prices and the ADD/NFIU production function is 20% higher than the rate which produces a MRR of 100%; for the same zone and crop the profit maximizing dose of DAP is 36% higher than the dose resulting in a MRR of 100%. Annex III provides additional illustrations of these differences.

## 4.2. Recent Changes in Profitability and Implications for Fertilizer Recommendations

In order to assess recent changes in fertilizer profitability, the value cost ratio (VCR)[21] has been calculated for the years 1992 (the year immediately after the grain market liberalization) and 1997 (after the removal of the fertilizer subsidy) using the fertilizer recommendations and yield responses reported by ADD/NFIU (Table 8). The results demonstrate that fertilizer profitability declined sharply between 1992 and 1997. Across the country, the VCR for teff declined by 55%, i.e. from 3.74 in 1992 to 1.69 in 1997. The sharpest fall was observed in the case of maize: its VCR declined by 67%. A decline of 48, 47 and 41% was observed for wheat, barley and sorghum, respectively.

In 1997, the VCR fell below the critical threshold of 2 for 71% of the site/crop combinations examined; in 1992 there were no cases less than 2. Among the five crops, only barley came out with a 1997 VCR consistently greater than 2 regardless of site. Wheat was the next most profitable crop, with an average VCR of 2 across all sites; two of the four sites examined attained a VCR greater than 2. The lowest profitability was observed in the case of maize and sorghum (VCRs of approximately 1.5). The VCR for teff, the most fertilized crop, was 1.7. The minimum teff price would have to increase by 19% over the harvest season price of 1997 for farmers to realize a VCR of 2 in the teff production areas of the Shoa region. In general, fertilizer use on barley, wheat and teff was more profitable in 1997 than use on maize and sorghum.

In practice, many farmers tend to reduce their rate of fertilizer application following higher fertilizer prices (relative to output prices). Indeed, the profit maximizing doses estimated using 1997 grain and fertilizer prices are substantially lower than those for 1992 (see Annex III). The analysis shows, for example, that the profit maximizing urea and DAP application rates in 1997 are 22% and 31% lower than those for 1992. This example (and additional examples shown in Annex III) suggests that fertilizer recommendations should be revised in response to large changes in market conditions; such revisions would be particularly important following the removal/reduction of fertilizer subsidies or changes in output market stabilization policies.[22] Although a sharp decrease in the profit maximizing fertilizer dose suggests that farmers should reduce their fertilizer applications, it does not mean that they should ignore the fact that lower fertilizer doses can result in serious loss of soil nutrients. When fertilizer becomes less profitable, research and extension services need to work harder to promote alternative practices to maintain soil fertility such as the use of crops residues and manure to increase soil organic matter.

[21] The value cost ratio (VCR) measures the return farmers receive from investing in fertilizer. It is generally believed that farmers would like to see a 100% return or a VCR equal to or greater than 2 in order to make the necessary investment decision.

[22] As neither farmers nor government know ahead of time what output prices will be in liberalized markets, perhaps what is needed is for the extension services to provide farmers with examples of a range of application rates/returns based on different price scenarios -- then the farmers can decide what they think the price will be and invest in fertilizer accordingly.

**Table 8. Value Cost Ratio Based on NFIU Trial Data**

| | Fert. cost 1997 | Incremental yield with fert. | Output Price, 1997 | VCR 1997 | VCR 1997 *1.2 | Fert. cost, 1992 | Output Price 1992 | VCR 1992 | Min Out. Price |
|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | d | e | f | g | h | i |
| Teff | | | | | | | | | |
| Shewa | 515.86 | 641.00 | 1.35 | **1.67** | 2.01 | 211.67 | 1.22 | **3.69** | 1.61 |
| Gojam | 480.48 | 592.00 | 1.35 | **1.66** | 1.99 | 197.26 | 1.22 | **3.66** | 1.62 |
| Arsi, Bale | 390.54 | 473.00 | 1.35 | **1.63** | 1.95 | 160.39 | 1.22 | **3.60** | 1.65 |
| Other | 222.60 | 195.00 | 1.35 | **1.18** | 1.41 | 91.98 | 1.22 | **2.59** | 2.28 |
| ATC | 468.42 | 590.00 | 1.35 | **1.69** | 2.03 | 192.25 | 1.22 | **3.74** | 1.59 |
| Wheat | | | | | | | | | |
| Shewa | 581.68 | 1091.00 | 1.12 | **2.09** | 2.51 | 238.52 | 0.88 | **4.03** | 1.07 |
| Gojam | 466.70 | 997.00 | 1.12 | **2.38** | 2.86 | 191.33 | 0.88 | **4.59** | 0.94 |
| Arsi, Bale | 585.12 | 826.00 | 1.12 | **1.57** | 1.89 | 240.36 | 0.88 | **3.02** | 1.42 |
| Other | 419.60 | 716.00 | 1.12 | **1.90** | 2.28 | 172.38 | 0.88 | **3.66** | 1.17 |
| ATC | 537.34 | 940.00 | 1.12 | **1.95** | 2.34 | 220.47 | 0.88 | **3.75** | 1.14 |
| Barley | | | | | | | | | |
| Shewa | 488.06 | 963.00 | 1.03 | **2.03** | 2.43 | 200.45 | 0.79 | **3.80** | 1.01 |
| Arsi, Bale | 528.26 | 1199.00 | 1.03 | **2.33** | 2.80 | 217.15 | 0.79 | **4.36** | 0.88 |
| Other | 466.46 | 1061.00 | 1.03 | **2.34** | 2.80 | 191.97 | 0.79 | **4.37** | 0.88 |
| ATC | 521.60 | 1129.00 | 1.03 | **2.22** | 2.67 | 214.26 | 0.79 | **4.16** | 0.92 |
| Maize | | | | | | | | | |
| Shewa | 471.98 | 1325.00 | 0.53 | **1.48** | 1.77 | 193.77 | 0.65 | **4.44** | 0.71 |
| Gojam | 720.20 | 1932.00 | 0.53 | **1.41** | 1.69 | 295.90 | 0.65 | **4.24** | 0.75 |
| Welega, Kefa, Illubab | 765.00 | 1855.00 | 0.53 | **1.28** | 1.53 | 314.10 | 0.65 | **3.84** | 0.82 |
| GamuGofa, Sidamo | 463.36 | 1212.00 | 0.53 | **1.38** | 1.65 | 190.60 | 0.65 | **4.13** | 0.76 |
| Other | 322.78 | 594.00 | 0.53 | **0.97** | 1.16 | 131.83 | 0.65 | **2.93** | 1.09 |
| ATC | 526.08 | 1410.00 | 0.53 | **1.41** | 1.69 | 216.08 | 0.65 | **4.24** | 0.75 |
| Sorghum | | | | | | | | | |
| Shewa | 324.60 | 759.00 | 1.04 | **2.44** | 2.92 | 133.86 | 0.72 | **4.08** | 0.86 |
| Hararghe | 196.98 | 248.00 | 1.04 | **1.31** | 1.57 | 81.83 | 0.72 | **2.18** | 1.59 |
| Other | 456.12 | 809.00 | 1.04 | **1.85** | 2.22 | 187.88 | 0.72 | **3.10** | 1.13 |
| ATC | 421.66 | 636.00 | 1.04 | **1.57** | 1.89 | 173.77 | 0.72 | **2.64** | 1.33 |

Source: NFIU trial data; EGTE price reports (for 1992 prices) and GMRP/EGTE Market Information System (1997 prices).
Notes: ATC = Across the country

As illustrated above, estimates of doses that maximize profits or ensure marginal rates of return of 100% can vary substantially when prices change; similar variation can occur when assumptions about fertilizer yield responses change. The 1992 and 1997 value/cost ratios reported in Table 8 assume fertilizer yield responses comparable to that attained during the ADD/NFIU trials which were conducted during years of only average rainfall. It is possible that with excellent rains (such as those experienced in 1996) or substantially improved management practices, a farmer's yield response might increase as much as 20 percent. Sensitivity analysis using a 20 percent increase in fertilizer response (added to ADD/NFIU response levels), shows that the VCR for several crop/region combinations can equal or exceed 2 even with 1997 input/output prices. This was generally true for teff, barely, and wheat but not so for maize and sorghum (column f, Table 8). These results suggest that one way of compensating for the price changes which occurred in 1997 would be to invest more in extension efforts that would improve farmers' ability to increase their fertilizer response (better weeding, timely planting, etc.). Although we do not present VCRs calculated with yields that are 20% lower than ADD/NFIU yields, it is clear that fertilizer profitability would be much lower than that already reported for 1997. As most of the 1997 VCRs are already below 2, the very real possibility of farmers obtaining yields lower than ADD/NFIU yields illustrates why the risk of bad years such as 1997/98 would create considerable strain on farmers and may seriously jeopardize repayment of fertilizer loan.

Among the main reasons for the declining profitability are the rising fertilizer prices relative to output prices.[23] Fertilizer prices have sharply increased in recent years because of devaluation, removal of subsidies, and imperfectly competitive fertilizer markets following liberalization of the fertilizer sector (Annex I). The major factors contributing to the drop in grain prices between 1992 and 1997 are abundant harvests and pressure on farmers to market their output immediately after harvest so they can pay off input credit, and limited expansion of the non-agricultural sector.[24]

In spite of the decline in the level of profitability, fertilizer use in the country has continued to increase for most of the years since 1992 (Annex I). At least two reasons can be given for this. First, although farmers are no longer able to get a return of 100% (VCR = 2), fertilizer is still profitable (not allowing for the risk of crop failure) with a return of 69% for teff, 95% for wheat, 122% for barley, 41% for maize, and 51% for sorghum. In view of the continuous cultivation system (due to shortage of land), fertilizer use may be viewed as profitable even though the rate of return has fallen below 100%. In the absence of alternative options to restore soil fertility, farmers have no choice but continue to invest in chemical fertilizers, although the return is inadequate to protect them against the various risks.[25] Second, the negative effects of the higher fertilizer prices may have been offset by other factors including the fertilizer market liberalization which has made fertilizer more available in many regions, improved access to credit, and the ongoing intensive extension effort. These issues are examined empirically in Section 5.3.

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[23] Grain Prices were extremely low immediately after the 1996/97 harvest.

[24] See also Mulat Demeke, et al. Promoting Fertilizer Use in Ethiopia: The Implications of Improving Grain Market Performance, Input Market Efficiency, and Farm Management, 1997.

[25] As indicated above, valuable assets are sold to pay for fertilizer cost whenever crop failures occur. As indicated by KUAWAB/DSA (1995), many farmers sell livestock to pay for fertilizer even in normal years.

Nonetheless, there is no guarantee that demand for fertilizer will continue to rise. Indeed, there are indications that demand may stagnate or even decline unless corrective measures are taken. For instance, sales have fallen far short of supply in the last two years (see section 2 above). More importantly, fertilizer demand actually declined (by 18.5%) between 1996 and 1997. This can be attributed to problems mentioned above (inefficient marketing, weak credit delivery system, and low profitability) and bad weather. It is also evident that these are not the only factors affecting demand. In this regard, it becomes imperative to look into the different factors affecting fertilizer sales or demand in Ethiopia. The next section attempts to identify these factors and assess their relative contributions.

## 5. IDENTIFYING AND EVALUATING THE RELATIVE IMPORTANCE OF FACTORS INFLUENCING FERTILIZER CONSUMPTION

The Ethiopian government has three parallel goals with respect to fertilizer policy:

(1) to increase the number of adopters,

(2) to increase the application rates of those adopting, and

(3) to improve the nutrient balance of fertilizer applied (i.e. increase nitrogen relative to phosphate).

In this section of the paper we provide insights that should help the government improve the design of policies to meet the first two goals. Specifically, we identify a range of factors that differentiate fertilizer users from non-users and then look into the factors that influence the intensity of fertilizer use (i.e. kilograms applied per hectare). In both cases, we quantify to the maximum extent possible the relative importance of these factors, thereby helping the government to identify areas of intervention likely to have the greatest impact on fertilizer demand.

Fertilizer decisions are made at the household level, so it is imperative to understand the set of factors influencing household decisions. To accomplish this we present a wide range of descriptive statistics on variables that explain fertilizer use and non-use by households as well as differences in the intensity of use. Some analyses concern the entire nation, while other analyses focus on the principal fertilizer-using regions.

Further analysis has been made at the wereda-level. This is an important complement to the household analysis because it helps us to separate factors that are household-specific from those that are related to residence in a particular wereda. The wereda level analysis also provides useful information for targeting government interventions as it is often easier to target a program to a geographic entity rather than to a particular type of household. In the wereda-level analysis we limit ourselves to the four regions where one would expect farmers in most weredas to be consuming fertilizer (Oromiya, Amhara, Southern, and Tigray).

Similar questions were asked at the household and for wereda-level analysis. Among the key questions addressed are: Why do some households or weredas in the higher fertilizer-use regions use no fertilizer at all? Why is average use per hectare higher in some households/weredas than in others? Are these differences strictly due to agroecological factors or are there other factors such as access to markets, credit, and infrastructure that need to be addressed?

In the household and wereda descriptive analysis, we look at the relationship between fertilizer use and the determining factors on a variable by variable basis. While such an approach is informative and provides us with a number of hypotheses about how each variable affects fertilizer use, the world is more complex. Each of the individual factors can be interacting with the other factors and it is important to understand how everything fits together to form a composite picture that more closely resembles reality. To accomplish this objective we developed a multivariate model using wereda-level data. The model looks at:

(1) factors that determine whether a wereda (i.e. the aggregate behavior of all households in the wereda) uses fertilizer or not, and

(2) factors that determine the intensity of use within the fertilizer-using wereda.

We begin this discussion with a brief review of the previous studies on fertilizer adoption in Ethiopia. This is followed by a section identifying the broad categories of factors that influence fertilizer use. We then turn to our analysis of the data, using the best available data (a combination of our own surveys and secondary data) to test the statistical relationship between these variables and observed fertilizer use. Finally we present and interpret the results of the multivariate model of fertilizer use at the wereda level.

### 5.1. A Brief Review of Factors Influencing Fertilizer Adoption and Intensity of Use

Fertilizer or adoption decisions are made at the household level, so it is imperative to understand the set of factors influencing household decisions. Previous adoption studies in Ethiopia have examined a wide range of factors; results have not always been consistent across studies. Itana (1985), for instance, showed that literacy, farm size, unavailability of cash for down payment, price of farm inputs and adequacy of rainfall were the most important determinants of agricultural technology adoption. Mulugeta (1995) found that access to credit, herbicide use, timely availability of fertilizer, farm size and oxen are the most important determinants of fertilizer adoption. More or less similar results were also obtained by Chilot, Shapiro and Mulat (1996). However, Teressa (1997), while drawing the same conclusions with respect to several variables, obtained a negative relationship between land size and fertilizer use. Asmerom and Alber (1994) also arrived at the conclusion that the use of fertilizer in North West and Central Ethiopia does not depend on farm resources such as capital and land to any significant degree. The seemingly inconsistent results for some important variables may be attributed to differences in the area of study, smallness of the sample size and of the model.[26] The relevance of the results beyond the districts of the study may also be limited.

The area coverage of the study by Croppenstedt and Mulat (1996) is probably the largest so far. All the main fertilizer consuming regions, namely Oromiya, Amhara, Southern Region and Tigray, were included. Attempts were also made to examine the impact of the ratio of output prices to fertilizer prices. The results showed that literacy status of the household head, access to all-weather road, access to banks, extensions services, and availability of labor play an important role in fertilizer adoption. The study also indicated that amount of fertilizer used (intensity of use) is influenced by several factors including previous experience with fertilizer, supply conditions, liquidity, oxen owned by the household, and the ratio of the price

[26] For instance, some variables such as risk factors, financial liquidity, agronomic circumstances influencing response to fertilizer application, cropping pattern, etc. were not consistently taken into account in all the studies.

of the main crop to the cost of fertilizer. However, the study failed to include farm size, cropping pattern and rainfall in the analysis.

The implications of improving the performance of grain and input marketing on the profitability of fertilizer use was analyzed by Mulat, Ali and Jayne (1997). Evidence suggests that certain institutional, legal, and policy aspects of the existing system of fertilizer importation distribution in Ethiopia impose unnecessary costs on purchasers of fertilizer and also depress grain prices. The study concluded that fertilizer profitability will significantly improve if grain and fertilizer marketing systems are made more competitive and efficient. The study, however, did not look into the implications of changes in profitability levels for fertilizer adoption. By way of conceptualizing the factors influencing fertilizer adoption and intensity of use, the factors influencing fertilizer demand have been grouped into the following seven categories.

*i. Profitability:* The profitability of fertilizer is among the major determinants of fertilizer use. Farmers will not be persuaded to adopt fertilizer unless its profitability is sufficiently high. The major factors influencing profitability are:

(a) the price of output;

(b) cost of fertilizer; and

(c) the response of output to fertilizer application.

The response rate itself is a result of the interaction of a large number of agronomic (largely controllable) and natural (uncontrollable) factors. The agronomic factors include land preparation, type of crop planted (cropping pattern), seed variety, seeding rate, planting time, method of fertilizer application, soil and water management, control of weeds insects, and balanced nutrient use. According to FAO (1987), incremental output to fertilizer application may decline by as much as 20 to 50% due to inappropriate crop variety, untimely planting and unbalance nutrient use. Among the uncontrollable variables are climate and soil type.

*ii. Risk Factors:* There are numerous risks and uncertainties associated with crop production and marketing. Some of the most important risks under the Ethiopian farming conditions are moisture stress and drought, excess rains, hailstorms, flooding, frost, crop pests such as army worm and grasshoppers and abnormal weed infestation. Some areas are characterized by a very high coefficient of both inter- and intra-year variability. Low and fluctuating output prices together with a sudden rise in input prices and delays/unavailability constitute marketing risks. High risk conditions imply that farmers are less inclined to invest on fertilizer.

*iii. Human Resources:* The quantity and quality of human resources possessed by a peasant household may be measured by the amount of family labor, educational background, age and gender of the household head. A positive relationship between education and fertilizer use, for instance, may signify the contribution of education to greater access to information about improved farming techniques. A larger family labor supply could also mean more timely planting and weeding practices, leading to a more efficient/profitable use of fertilizer. Female-headed households are often underprivileged and may have poor access to credit and other inputs, hence they may be less likely to use fertilizer.

*iv. Extension Services:* Farmers' attitudes towards technology adoption are influenced by extension services. Many studies have shown that people who have adopted innovations have frequent contact with change agents. The skill of the extension agents and the extent to which the agent understands and accepts the farmer perspective has considerable influence on adoption.

*v. Household Assets:* Amount of land under cultivation, number of draft animals and other livestock owned are among the most important assets in the rural sector. Households with fewer resources are expected to have a different attitude towards risk than those with more resources. Resource-poor farmers may not be willing to face the risk of using fertilizer when there is a possibility of crop failure due to drought. Shortage of oxen could also mean poor land preparation and failure to plant at the right time, thus discouraging farmers from buying fertilizer, and also lowering the output response to fertilizer use.

*vi. Financial Liquidity:* Finance is a critical bottleneck in purchasing fertilizer. The amount of cash required to purchase the input is often beyond the means of most farmers. Several studies on Ethiopia have shown that access to credit and the liquidity position of the farmer are among the most important determinants of fertilizer use. Cash may be required for a down-payment even in the case of credit purchases. Households growing cash crops are expected to have better liquidity positions.

*vii. Market Access and Structure:* The degree of commercialization tends to be positively correlated with access to roads. In zones where road infrastructure is poor and transportation costs are high farmers are generally less likely to use modern inputs such as fertilizer. Access to inputs is also affected by the number of sales/retail outlets (accessibility) in a given area (e.g. wereda) and competitiveness of the input markets.

### 5.2. Descriptive Analysis

Table 9 shows the proportion of households and weredas using chemical fertilizer in 1995/96 for selected regions and nationwide.

**Table 9. Percent of Households and Wereda Using Chemical Fertilizer in Four Major Fertilizer-Consuming Regions and Nationwide**

| Region | Percent of Households Using Fertilizer | Percent of Wereda Using Fertilizer* |
|---|---|---|
| Tigray | 21.3% | 77.4% |
| Amhara | 23.7% | 61.3% |
| Oromiya | 40.0% | 74.5% |
| SNNPR | 29.2% | 61.7% |
| Nationwide | 31.2% | 68.9% |

* i.e., percent of weredes in which at last one household in the sample surveyed in the CSA Production Survey 1995/96 used fertilizer.

Across the entire nation, 31% of the households used fertilizer while the vast majority (close to 70%) did not. The percent of households using fertilizer varies substantially by region, even among the top four consuming regions shown in Table 9. Among these four, Oromiya has the largest percent of users (40%) and Tigray has the lowest percent (21).

The proportion of weredas using fertilizer (defined as weredas reporting households who use fertilizer - regardless of the number involved) is larger than the proportion of user households. As a whole, the use of fertilizer was reported by at least one household in the sample of 360 weredas in 69 % of the weredas under consideration. In the CSA surveys, roughly 20 households were sampled in each wereda. The proportion of user weredas was larger for Tigray (77%) and Oromiya (75%) than for Amhara (61%) and Southern region (62%). The high percent of weredas covered in Tigray indicates that fertilizer was more widely distributed (geographically speaking) than what may be inferred from the proportion of user households. In other words, fertilizer has been introduced in a larger proportion of weredas in Tigray, but the number of user households in each wereda is not proportionately as large as in other zones.

In order to get an even clearer picture, user and non-user weredas have been identified by region and zone (Table 10). The result shows that the variations in percent of weredas using fertilizer are frequently quite important across zones within the same region. For instance, the proportion of weredas in the Amhara region where fertilizer was used ranges from 0% in Wag Hamra to 91% in West Gojam. User-weredas are a small proportion of total wereda in the North Wello (13%), South Wello (31%), North Gondar (36%) and Oromiya (40%) zones of the Amhara region. Most weredas in the more drought-prone areas (former Wello and North Gondar areas of the current Amhara Region) do not use fertilizer. In Oromiya, a 100% use rate was found in West Shoa, East Shoa and Arssi, as compared to just 14% in Borena and 33% in West Hararghe. Over 50% of the weredas use fertilizer in the other zones of the Oromiya region. The contrast across zones is more pronounced in SNNPR: fertilizer distribution is concentrated in five zones Hadiya (100%), Kembata Alaba Timbaro (100%), Guraghe (88%) and they are found in the other special weredas and some of the small zones of the SNNPR region. Sidama (88%) and Yem special wereda (100%). There are 6 wereda that use no fertilizer. The distribution of fertilizer by zone appears to be more uniform in Tigray as the percent of user-weredas is over 70 in all four zones of the region.

**Table 10. Percentage of Weredas Using Chemical Fertilizers By Zone for the Four Major Fertilizer-Consuming Regions**

| Region | Zone | Percentage of Weredas Using Fertilizer | Region | Zone | Percentage of Weredas Using Fertilizer |
|---|---|---|---|---|---|
| Tigray | Tigray West | 0.83 | SNNPR | Gurage | 0.88 |
| | Tigray Centre | 0.73 | | Hadiya | 1 |
| | Tigray East | 0.71 | | Kembata Alaba | 1 |
| | Tigray South | 0.8 | | Sidama | 0.88 |
| Amhara | Gonder North | 0.36 | | Gedeo | 0.5 |
| | Gonder South | 0.75 | | Omo North | 0.47 |
| | Wello North | 0.13 | | Omo South | 0.5 |
| | Wello South | 0.31 | | Shekicho | 0.33 |
| | Shewa North | 0.79 | | Kaficho | 0.13 |
| | Gojjam East | 0.79 | | Bench | 0 |
| | Gojjam West | 0.91 | | Maji | 0 |
| | Wag himira | 0 | | Yem Special Wereda | 1 |
| | Agawawi | 0.67 | | Amaro Special Wereda | 0 |
| | Oromia zone | 0.4 | | Burji Special Wereda | 0 |
| Oromiya | Wellega West | 0.59 | | Konso Special Wereda | 0 |
| | Wellega East | 0.88 | | Derashe Special Wereda | 0 |
| | Illubabor | 0.72 | | | |
| | Jimma | 0.91 | | | |
| | Shewa West | 1 | | | |
| | Shewa North | 0.79 | | | |
| | Shewa East | 1 | | | |
| | Arssi | 1 | | | |
| | Harerge West | 0.33 | | | |
| | Harerge East | 0.58 | | | |
| | Bale | 0.78 | | | |
| | Borana | 0.14 | | | |

A number of reasons may be given for the observed variations in fertilizer use. The following section is about the factors that contribute to the observed variations.

*i. Fertilizer Profitability:* The proxy variables used to reflect factors influencing fertilizer profitability were cropping pattern (i.e., share of area planted to different crops), use of complementary inputs, average rainfall and altitude. The fertilizer adoption rate was hypothesized to be higher in the case of more profitable crops such as teff and wheat, usage of complementary inputs, higher rainfall and higher altitude areas.

The relationship between fertilizer use and area cultivated for cereal crops is shown on Table 11 for the major fertilizer consuming regions. Across these four regions, the share of teff in total area cultivated is larger for fertilizer-using households (26%) than Non using households (17%). The difference in percent of area planted to teff by users and nonusers is significant in all regions but Tigray. Wheat is also popular among fertilizer users, with significantly higher percentages of area cultivated by users for the four zones combined as well as for Amhara, Oromiya and SNNPR. The situation with respect to maize is mixed: fertilizer users have a statistically <u>larger</u> share of cultivated area devoted to maize in Amhara and SNNPR but significantly <u>smaller</u> share in Oromya. The overall average across the four zones reflects the Amhara/SNNPR results: fertilizer users have a statistically larger share of area planted to maize than nonusers. Percent of area in sorghum is generally low for users and high for nonusers, with results statistically significant in all zones but Tigray.

The preference for teff and wheat production among users is partly related to profitability. As shown in Section IV, fertilizer use on these crops is more profitable than on sorghum or maize. But other factors, such as relatively more stable and higher prices for teff and wheat may also encourage (and enable) teff and wheat farmers to use fertilizer. The tendency for farmers with a large percent of area planted to sorghum to be nonusers can be understood given the lower profitability of fertilizer on this crop and the fact that it is grown in areas characterized by high risk of crop failure due to drought.

The proportion of households using improved seeds, pesticides, and irrigation is generally very small. These practices are, however, more common among fertilizer users than noun-users. For instance, fertilizer-using weredas have a larger percent of farmers using improved seeds and/or pesticides in all regions but Amhara. Overall, some 4% and 17% of the farmers in user-weredas reported using improved seeds and pesticides, respectively. By contrast, only 2% and 3% of the households in the non-user weredas made use of improved seeds and pesticides, respectively (see Annex IV). Users seem to realize that profitability is higher when fertilizer is used with complementary inputs, though these are not widely available. Irrigation is also slightly more common among users than non-users but the difference is never statistically significant.

The most interesting finding concerning complementary practices is that wereda using fertilizer have a statistically higher percent (11 to 17) of farmers also using manure in all regions but Tigray. This suggests that manure may be used as a complement to fertilizer as well as a substitute for it. It also suggests that resource-poor farmers who do not have access to chemical fertilizers may also not have access to manure; fewer than 50% of farmers in all the non-using weredas reported using manure (see Annex IV).

Although higher rainfall is usually associated with higher fertilizer adoption, the wereda-level results were mixed (Table 12). Fertilizer-using wereda in Amhara had statistically higher rainfall than nonusers but in SNNPR the results were reversed -- nonusers had statistically

## Table 11. Comparison of Percent of Area Cultivated by Crop and Region for Fertilizer-Using and Non using Households

| | Teff | | Maize | | Wheat | | Barley | | Sorghum | | Millet | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CROP: | Non-user | User | Non-User | User | Non-User | User | Non-User | User | Non-User | User | Non-User | User |
| Mean values in the table are for share of cultivated area devoted to each crop by type of farmer (i.e., fertilizer users and non-users) calculated from household-level observations. | | | | | | | | | | | | |
| Tigray | | | | | | | | | | | | |
| Mean | 0.19 | 0.2 | 0.08 | 0.09 | 0.22 | 0.18 | 0.19 | 0.22 | 0.16 | 0.13 | 0.1 | 0.1 |
| Sig Dif | | | | | | | | | | | | -.04* |
| Amhara | | | | | | | | | | | | |
| Mean | 0.21 | 0.36 | 0.09 | 0.13 | 0.08 | 0.1 | 0.15 | 0.07 | 0.21 | 0.09 | 0 | 0.07 |
| Sig Dif | | -.15*** | | -.03*** | | -.02* | | +.08*** | | +.12*** | | -.04*** |
| Oromya | | | | | | | | | | | | |
| Mean | 0.14 | 0.26 | 0.21 | 0.17 | 0.06 | 0.14 | 0.09 | 0.09 | 0.19 | 0.09 | 0 | 0.01 |
| Sig Dif | | -.12*** | | +.03** | | -08*** | | | | +.10*** | | +.007** |
| SNNPR | | | | | | | | | | | | |
| Mean | 0.13 | 0.18 | 0.13 | 0.18 | 0.02 | 0.11 | 0.07 | 0.06 | 0.15 | 0.04 | 0 | 0 |
| Sig Dif | | -.04** | | -.04** | | -.09*** | | | | +.10*** | | |
| TOTAL | | | | | | | | | | | | |
| Mean | 0.17 | 0.26 | 0.14 | 0.16 | 0.07 | 0.13 | 0.11 | 0.09 | 0.18 | 0.08 | 0 | 0.03 |
| Sig Dif | | -.09*** | | -.02** | | -.06*** | | +.02*** | | +.10*** | | -.008** |

higher rainfall. Differences were not significant for Tigray and Oromya, as well as for the overall results across the four zones. Our hypothesis is that some areas of SNNPR may experience flooding that increases risk of crop loss and reduce fertilizer profitability. It must be noted also, that an estimate of average rainfall for an entire wereda is only a rough approximation of rainfall levels faced by farmers cultivating under a wide variety of rainfall outcomes; our measure of rainfall may not be accurate enough to correctly capture the relationship between rainfall and fertilizer profitability (Table 12).

A statistically higher altitude was observed in weredas that use fertilizer for the SNNPR and Oromiya regions; the results were also statistically significant for the average across all four zones (Table 12). Although the differences were not statistically significant for Amhara and Tigray, differences that were significant are in the anticipated direction -- higher altitude is generally associated with more fertilizer use.

The analysis of ecological factors confirm that higher rainfall (which does not lead to flooding) and higher altitudes generally provide growing conditions that encourage fertilizer use.

**Table 12. Comparison of Mean Rainfall and Altitude for Weredas in Which Fertilizer is Used vs. Not Used**

| | Rainfall (mm) | | Altitute (m) | |
|---|---|---|---|---|
| Region | Don't Use | Use Fertilizer | Don't Use | Use Fertilizer |
| Tigray | | | | |
| Mean | 700 | 737 | 2026 | 2148 |
| Mean dif | | -37 | | -122 |
| Amhara | | | | |
| Mean | 1061 | 1218 | 2164 | 2147 |
| Mean dif | | -157*** | | 18 |
| Oromya | | | | |
| Mean | 1227 | 1301 | 1778 | 2095 |
| Mean dif | | -74 | | -317*** |
| SNNPR | | | | |
| Mean | 1422 | 1220 | 1827 | 2170 |
| Mean dif | | +202** | | -344*** |
| All four regions | | | | |
| Mean | 1188 | 1204 | 1941 | 2126 |
| Mean dif | | -15.7 | | -185*** |

Source: GMRP/CSA surveys 1996, and World Food Programme for Map Info data on elevation and rainfall.
Notes: Mean differences marked with asterisks are significantly different from zero at 90% level of probability (*), 95% level (**) and 99% (***).

*ii. Production Risks:* The degree to which farmers are constrained by risk factors in using fertilizer is assessed using proxy variables such as percent of households which received food aid at least once during 1991-1995 and percent of households reporting crop damage in 1995/96. Overall, 45% of the households in the non-user weredas received food aid, compared to 30%in fertilizer user weredas (Table 13). The difference was statistically significant for the overall results across the four zones and each individual zone except Tigray.

As anticipated, fertilizer adoption is also lower in weredas where a high percent of households reported experiencing crop damage (Table 13). High risk of crop damage, whether it comes from climatic factors, pests, or disease, makes investment in fertilizer unattractive. This can be particularly true for resource-poor farmers with few assets to fall back on when losses from crop damage are severe.

**Table 13. Comparison of Risk Indicators (Food Aid and Crop Damage) for Wereda Not Using and Using Fertilizer**

| | % of HH in wereda that received food aid at least once during the 1991-1995 period | | % of HH in wereda reporting crop damage during the 1995/96 meher season | |
|---|---|---|---|---|
| KILLIL | Wereda region doesn't use fertilizer | Wereda uses fertilizer | Wereda region doesn't use fertilizer | Wereda uses fertilizer |
| Tigray | | | | |
| Mean | 89.80 | 83.43 | 65.9 | 69.8 |
| Mean dif | +6 | | | -3.9 |
| Amhara | | | | |
| Mean | 61.9 | 21.12 | 87.6 | 72.9 |
| Mean dif | +41*** | | | +15*** |
| Oromya | | | | |
| Mean | 40.16 | 20.31 | 65.7 | 67.5 |
| Sig dif | +20*** | | | -1.8 |
| SNNPR | | | | |
| Mean | 17.92 | 32.47 | 62.7 | 67.2 |
| Mean dif | -15* | | | -4.4 |
| All four regions | | | | |
| Mean | 45 | 30 | 72.5 | 69.0 |
| Mean dif | +15*** | | | +3.6 |

Source: Calculated from CSA production survey data (334 wereda-level observations).
Notes: Mean differences marked with asterisks are significantly different from zero at 90% level of probability (*), 95% level (**) and 99% (***).

*iii. Extension Services:* Overall, about 59% of the households in the fertilizer using category knew about the new extension program (NEP), compared to only 43% in the non-using group (Table 14). The difference is statistically significant for all regions but Tigray. A similar statistically significant difference was observed with respect to whether or not the household participated in NEP. For the entire sample, 12% of the households in the user group participated, as opposed to only 3% in the non-user group (Table 14). The difference was particularly large, 20%, in the case of Tigray, perhaps an indication that the extension program is the most important factor in the adoption of fertilizer in the region[27].

iv. *Human Resources*: For the overall sample, the literacy rate among the fertilizer using households was 7% higher than among nonusers and the difference was statistically significant (Table 14). The results generally confirm that literacy has a positive influence on fertilizer adoption. But it should be noted that although the percentage of literate household heads was larger in the user group for all regions but Tigray, the difference was large enough to be statistically significant only in the case of Amhara. In other words, the Amhara results are largely responsible for the statistical significance of the aggregated results across the four zones.

No significant difference was observed between the two groups with respect to age (Table 14). Similarly, experience in farming (measured by the number of years the respondent has been operating as a farmer) is not significant for any of the regions. The significance of the experience variable for the overall sample, however, does suggest that users have slightly longer experience in farming than non-users.

The evidence does not support the argument that female headed households have fallen behind their male counterparts in terms of fertilizer adoption. For the entire sample, the percentage of female heads in the users group was 15% compared to 13% for nonusers and the difference was not statistically significant (Table 14). The same insignificant difference was obtained for Amhara and Oromiya. However, the pattern was inconsistent in the case of Tigray and SNNPR: significantly larger percent of female headed households among users group in SNNPR but smaller in Tigray.

[27] In Tigray, fertilizer adoption is not related to most other variables.

**Table 14. Comparison of Mean Values for some Characteristics of Household Heads Using and Not Using Fertilizer during 1991/92-1995/96**

| | % knowing about New Extension Program (NEP) | | % having participated in NETP (xx) | | Age of household head | | % of female literate household heads | | % of female household heads | |
|---|---|---|---|---|---|---|---|---|---|---|
| KILLIL-Region | Didn't Use | Use Fert. | Didn't Use | Use Fert. | Didn't Use | Use Fert. | Didn't Use | Use Fert. | Didn't Use | Use Fert. |
| Tigray | | | | | | | | | | |
| Mean | 0.72 | 0.77 | 0.12 | 0.32 | 47 | 46 | 0.14 | 0.11 | 0.22 | 0.09 |
| Mean Dif | | -.20*** | | | | | | | | .14*** |
| Amhara | | | | | | | | | | |
| Mean | 0.34 | 0.53 | 0.02 | 0.11 | 45 | 43 | 0.17 | 0.33 | 0.12 | 0.08 |
| Mean Dif | | -.19*** | | -.09*** | | | | -.16*** | | |
| Oromiya | | | | | | | | | | |
| Mean | 0.49 | 0.63 | 0.02 | 0.12 | 43 | 45 | 0.25 | 0.28 | 0.14 | 0.16 |
| Mean Dif | | -.14*** | | -.10*** | | | | | | |
| SNNPR | | | | | | | | | | |
| Mean | 0.37 | 0.52 | 0.01 | 0.08 | 42 | 42 | 0.28 | 0.31 | 0.09 | 0.22 |
| Mean Dif | | -.15*** | | -.06*** | | | | | | -.12*** |
| All Four Regions | | | | | | | | | | |
| Mean | 0.43 | 0.59 | 0.03 | 0.12 | 44 | 44 | 0.22 | 0.29 | 0.13 | 0.15 |
| Mean Dif | | -.17*** | | -.09*** | | | | -.07*** | | |

Source: Calculated from CSA (age, literacy, gender of household head) and FS (all other variables) survey data, 1995/96
Notes: Mean differences marked with asterisks are significantly different from zero at 90% level of probability (*), 95% level (**) and 99% (***).

*v. Household Assets:* Household assets are represented by the number of tropical livestock units (TLU) owned per household and per capita, farm size in hectares, and the number of traction animals owned per household. The results, as shown on Table 15, are consistent with the argument that fertilizer users are likely to have more assets. Fertilizer using households on the average own 5 TLU, as opposed to 3.65 in the case of nonusers. This difference (in favor of users) is true for the overall sample and for all regions except SNNPR. With respect to the number of TLU, the difference is less pronounced but it is still statistically significant in Oromiya and for the overall sample.

A similar marked distinction between users and non-users was observed with respect to ownership of traction cattle. On the average, fertilizer users owned 1.52 draft cattle, while nonusers owned only 0.99. The difference between the user and nonuser groups is more conspicuous in the case of Oromiya (.84 animals) and Amhara (0.54) than for the other regions.

For the entire sample, fertilizer users have 9% more households using animal traction than nonusers. The differences (in percent of households using traction among fertilizer users and nonusers) ranged from 1% in Amhara to 14% in Oromiya and SNNPR. Access to traction animals is positively associated with fertilizer use in all regions except Tigray where no difference between users and nonusers was found. Overall, the use of draft animals is very high (87%) for the survey regions; the percentage ranges from a low of 69% in SNNPR (where farm size is the smallest) to a high of 99% in Tigray. While many small farmers in SNNPR manually cultivate/dig their farm (true for enset areas), such practice seems to be non-existent in the north, particularly Tigray.

Table 16 examines the relationship between farm size and fertilizer use. Farmers who used fertilizer in Amhara and Oromiya cultivated more total land (.76 to .83 hectare more) and more land per person (0.13 hectares more per person) during the meher season of 1995/96 than farmers who did not use fertilizer. These are large differences given that average farm size for the overall sample is only 1 hectare. In Tigray and SNNPR, on the other hand, there is no statistically significant farm-size difference between users and non-users. But the overall sample results are similar to those for Amhara and Oromiya, which have the largest number of weighted observations.

The result that non-users cultivate smaller land than users contradicts the argument that intensification is (or should be) higher on smaller farms (to compensate for land shortage). The reason may be found in the nature of smaller farm in Ethiopia. Households with very small plots seldom produce enough grain to meet their family's consumption requirements.[28] Such families (unless they rely on *enset* as in SNNPR or food aid as in Tigray[29]) are likely to be dependent on the market for their food. Some families (e.g. poor families with no oxen and very little family labor) may largely rely on income earned from rented-out or sharecropped land and retain only a small plot which is planted without fertilizer. Others are more likely to be involved in various non-farm activities and wage employment (e.g food for work) to survive. Even with fertilizer, many may not be able to produce for the market. They may be reluctant to invest their cash income in fertilizer (instead of buying food from the market) because of the risk involved. Poorer households often tend to be more risk-averse than better-off farmers. Households with more animals tend to have a better financial and traction capacity and are more likely to withstand the risk of crop failure (for they can pay fertilizer debts by selling animals). Our result show that given current prices and policies, small farm size appears to act as a barrier to fertilizer adoption.

**Table 15. Comparison of Mean Values of Asset Indicators for Farmers Using and Not Using Fertilizer During 1991/92-1995/96**

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[28] Since the average yield of cereals is about 10 quintals, farmers with small holdings, say 0.5 ha, can only manage to produce 5 quintals which is hardly enough to feed a family of 5 or 6 mouths

[29] See for instance Daniel C. Clay, et al., Improving Food Aid Targeting in Ethiopia: A Study of Food Insecurity and Food Aid Distributions, GMRP/MEDAC, 1997, forthcoming.

| KILLIL-Region | TLU | | TLU/capita | | Use animal traction | | % of H.H. owning cattle | | Number of traction cattle owned | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Didn't Use | Used Fert. | Didn't Use | Used Fert. | Didn't Use | Used Fert. | Didn't Use | Used Fert. | Didn't Use | Used Fert. |
| Tigray | | | | | | | | | | |
| Mean | 4.11 | 5.64 | 0.78 | 0.87 | 0.99 | 1 | 0.75 | 0.88 | 1.35 | 1.65 |
| Sig Dif | | -1.53*** | | | | | | -.13*** | | -.30* |
| Amhara | | | | | | | | | | |
| Mean | 3.39 | 4.36 | 0.66 | 0.69 | 0.97 | 0.99 | 0.73 | 0.84 | 1.2 | 1.74 |
| Sig Dif | | -.98*** | | | | -.02* | | -.11*** | | -.54*** |
| Oromiva | | | | | | | | | | |
| Mean | 3.8 | 5.7 | 0.73 | 1.01 | 0.81 | 0.95 | 0.56 | 0.77 | 0.94 | 1.78 |
| Sig Dif | | -1.90*** | | -.28*** | | -.14*** | | -.20*** | | -.84*** |
| SNNPR | | | | | | | | | | |
| Mean | 3.23 | 3.49 | 0.55 | 0.61 | 0.64 | 0.78 | 0.39 | 0.43 | 0.62 | 0.62 |
| Sig Dif | | | | | | -.14*** | | | | |
| TOTAL | | | | | | | | | | |
| Mean | 3.65 | 5 | 0.68 | 0.86 | 0.84 | 0.93 | 0.6 | 0.72 | 0.99 | 1.52 |
| Sig Dif | | -1.48*** | | -.19*** | | -.09*** | | -.12*** | | -.53*** |

Source: Calculated from FS (use animal traction, use own traction) and CSA (all other variables) survey data, 1995/96

**Table 16. Comparison of Mean Values of Land Access Indicators for Farmers Using and Not Using Fertilizer During 1991-1995 Period**

| | Meher Hectares Cultivated | | Meher Hectares Cultivated Per Person | |
|---|---|---|---|---|
| Region | Non-User | User | Non-User | User |
| Tigray | | | | |
| Mean | .96 | 1.10 | .22 | .21 |
| Sig dif | | | | |
| Amhara | | | | |
| Mean | 1.09 | 1.92 | .24 | .37 |
| Sig dif | | -.83*** | | -.13*** |
| Oromya | | | | |
| Mean | .97 | 1.74 | .20 | .33 |
| Sig dif | | -.76*** | | -.13*** |
| SNNPR | | | | |
| Mean | .61 | .62 | .12 | .12 |
| Sig Dif | | | | |
| Total mean | .93 | 1.50 | .20 | .29 |
| Sig dif | | -.09*** | | -.57*** |

Source: Analysis of CSA and Food Security 1995/96 survey data (N=2597)

*vi. Financial Liquidity:* Financial liquidity of a farmer is proxied by physical proximity to a bank, membership in a service cooperative, and net market position (sales minus purchases of grain) in a year of average rainfall. Indeed, Table 17 demonstrates that all but the net market position are important determinants of fertilizer adoption. The average number of banks per wereda is 0.32 for user weredas, compared to 0.19 for non-users. But the difference is statistically significant only for the overall sample and SNNPR. The percent of households declaring to be members of service cooperative is also higher and statistically significant for user weredas in SNNPR, Oromiya, Amhara and for the overall sample. Fertilizer credit is generally made available through service cooperatives.

**Table 17. Comparison of Liquidity Indicators for Wereda Not Using and Using Fertilizer**

| Region | Average number of banks per wereda: Wereda doesn't use fert. | Wereda uses fert. | Mean diff. | % of households in wereda declaring membership in a service cooperative: Wereda doesn't use fert. | Wereda uses fert. | Mean diff. | % of households in wereda with positive net marketing position for cereals in a year of average rainfall: Wereda doesn't use fert. | Wereda uses fert. | Mean diff. |
|---|---|---|---|---|---|---|---|---|---|
| Tigray | .00 | .12 | -.12* | 36.7 | 46.9 | -10 | 35 | 26 | -8 |
| Amhara | .15 | .32 | -.17 | 28.3 | 43.1 | -15** | 30 | 29 | <1 |
| Oromya | .36 | .31 | +.05 | 11.5 | 29.1 | -18*** | 22 | 24 | -2 |
| SNNPR | .07 | .51 | -.45*** | 27.3 | 43.8 | -17** | 23 | 27 | -3 |
| All four regions | .19 | .32 | -.14** | 23.2 | 36.9 | -14*** | 26 | 26 | <1 |

Source: Calculated from FS survey data collected in 1995/96 and secondary data from Commercial Bank of Ethiopia and Development Bank of Ethiopia

Notes: Mean differences marked with asterisks are significantly different from zero at 90% level of probability (*), 95% level (**) and 99% (***).

That access to credit in rural areas is a critical bottleneck that can be clearly seen if one looks at the distribution of bank branches by wereda. As shown on Table 18, a total of 294 weredas or 79.2% of the sample weredas have no bank branches at all. There is 1 bank in 54 weredas (14.6%), 2 in 19 weredas (5.1%), 3 in 3 weredas (0.8%) and 4 banks in only 1 wereda (0.3%). Micro-financing schemes are largely non-existent to fill the gap. Limited access to banks has affected both the farmer and the small dealers in the rural areas.

**Table 18. Distribution of Banks (Bank Branches) by Wereda**

| | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| No banks | 294 | 79.2 | 79.2 |
| 1 bank | 54 | 14.6 | 93.8 |
| 2 banks | 19 | 5.1 | 98.9 |
| 3 banks | 3 | 0.8 | 99.7 |
| 4 banks | 1 | 0.3 | 100 |
| Total | 371 | 100 | |

Source: Commercial Bank of Ethiopia and Development Bank of Ethiopia

*vii. Market Access:* Table 19 provides a comparison of user and non-user weredas by access to market and number of fertilizer distribution centres. The proportion of households located within 10 kms from a place where grains are exchanged is larger for user woredas but the difference is significant only for Amhara. A more important factor in fertilizer use is rather found in the number of fertilizer distribution centres per wereda. Fertilizer-using weredas across the four zones have 6 more distribution centers per wereda than non-using weredas. There are also statistically significant differences at the regional-level in all cases but Tigray; the significant differences range from 4 in SNNPR to 7 in Oromiya.

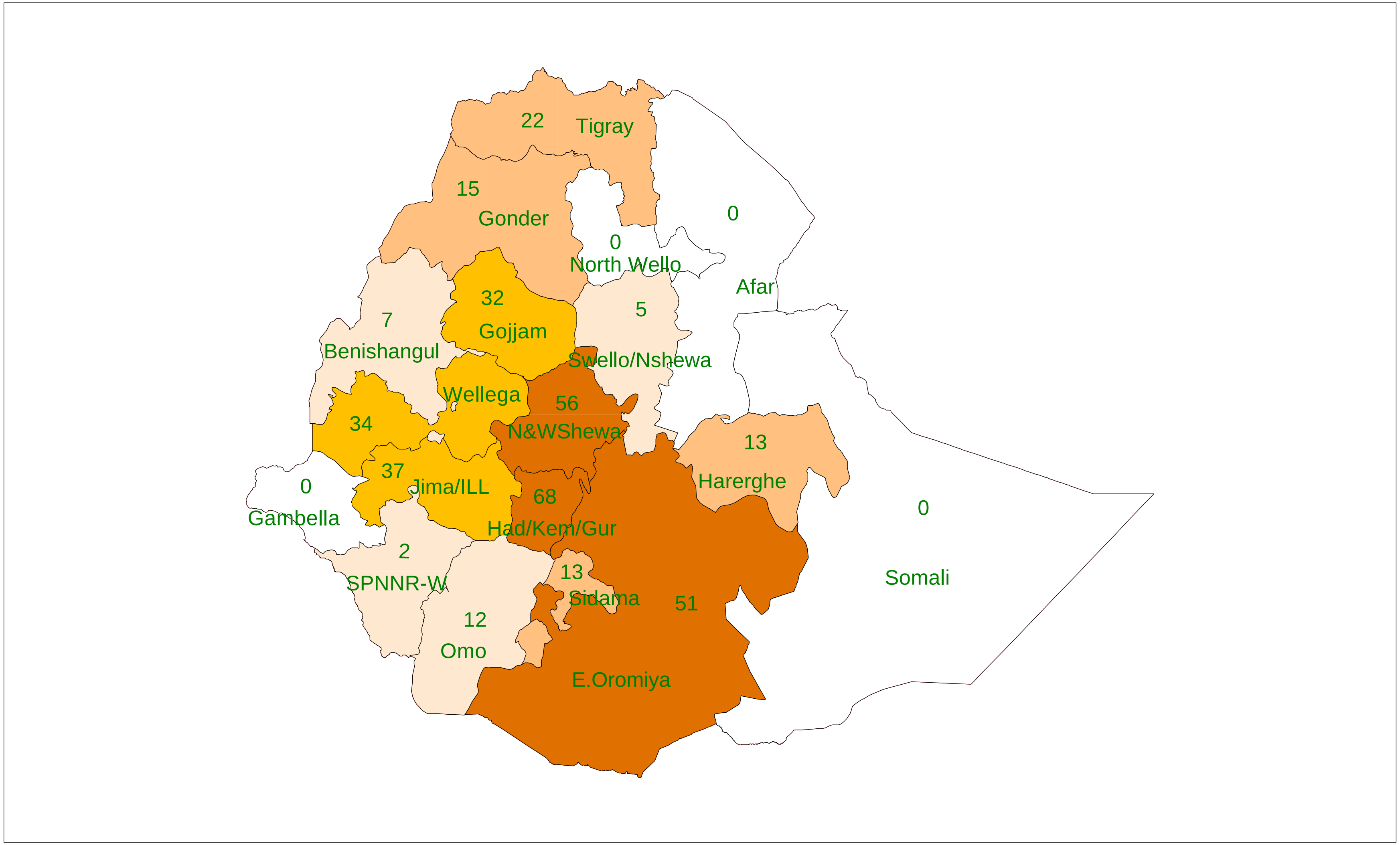
Figure 1 shows the zonal distribution of fertilizer-use intensity and road network for the country. For the most part, the intensity of fertilizer use is concentrated in zones with better road infrastructure. East Shoa (from Oromiya) and Kembata Alaba Timbaro (from SNNPR) have the highest application rate (100 to 180 kg per hectare) followed by Arssi, West Shoa and East Hararghe (from Oromiya), East and West Gojam (from Amhara), and Gurahe and Hadiya (from SNNPR). Apart from improved access to roads, these zones also benefit from good growing conditions.

## Table 19. Comparison of Market Access Indicator for Wereda Not Using and Using Fertilizer

| | % of major cereal purchases made less than 10 km from home | | Average number of distribution centers per | |
|---|---|---|---|---|
| Wereda | Wereda doesn't use fert. | Wereda uses fert. | Wereda doesn't use fert. | Wereda uses fert. |
| KILLIL Region | | | | |
| Tigray | | | | |
| Mean | 40.78 | 59.50 | 16 | 15.9 |
| Mean dif | | -19 | | +1 |
| Amhara | | | | |
| Mean | 58.43 | 71.99 | 11.5 | 16.2 |
| Mean dif | | -14* | | -4.74** |
| Oromya | | | | |
| Mean | 81.06 | 82.55 | 12.2 | 19.3 |
| Mean dif | | -1 | | -7*** |
| SNNPR | | | | |
| Mean | 90.01 | 91.93 | 4.8 | 8.7 |
| Mean dif | | -2 | | -4*** |
| All four regions | | | | |
| Mean | 73.04 | 79.12 | 10.5 | 16.4 |
| Mean dif | | -6 | | -5.95*** |

Source: Calculated from FS survey data collected in 1995/96.
Notes: Mean differences marked with asterisks are significantly different from zero at 90% level of probability (*), 95% level (**) and 99% (***).

**Figure 1: Percentage of Fertilizer Use by Domain for Ethiopia**



## 5.3 Household-level Decisions to Change the Level of Fertilizer Used

Among the 823 respondents replying that they had either increased or decreased quantities of fertilizer used over the last five years (1991/91 - 1995/96), 477 increased and 346 decreased. Looking at the results by region, we find that Tigray was the only region where decliners outpaced advancers (27 decreased and 24 increased). Farmers reporting increases in the amount of fertilizer used were further asked about their first and second most important reasons for this decision. The first and second responses were combined to create an index in which all first responses were given a weight of 2 and all second responses a weight of 1. The results for the frequencies of the index are given in Table 20.

**Table 20. Frequency Distribution of Reasons for Increasing Fertilizer Use from 1991/92 - 1995/96**

| Reasons for Increasing Quantity of Fertilizer | Frequency of Combined Weighted Responses |
|---|---|
| Declining soil productivity | 634 |
| Success in using fertilizer on farm | 515 |
| Improvement in availability | 137 |
| Increase in credit availability | 21 |
| Other | 14 |

Source: Calculated from 479 first responses and 379 second responses to Question Q6.1 in FS 1995/96 survey.

Overall, declining soil productivity is the most important reason for increasing the level of fertilizer use. It seems that the natural process of continuous cultivation without replenishing soil nutrients is the major factor driving farmers to increase fertilizer use. Hence programs to stimulate adoption may need to be focused in areas where farming practices have shifted to intensive or continuous cultivation resulting from population pressure or shortage of land.

The next very important reason in increasing fertilizer quantities is farmers' ability to correctly use fertilizer. Success in using fertilizer seems to be followed by increased application of fertilizer. Bad experience, especially in the initial stages, may serious constrain adoption. It is thus important to have good extension programs to make sure that farmers are successful with their initial forays into intensification with fertilizer. Among the other less important reasons for increasing use rates are improved availability of both the input and credit supply. Note that the relatively low number of responses for these categories do not mean that credit and availability are not important; the low response rate simply means that during the period in question there were few changes in availability or credit that stimulated increases in use.

The most important reason for reducing fertilizer use levels during the period 1991/92 - 1995/96 was the increase in the cost of fertilizer (Table 21). Some farmers seem to have failed to withstand the sharp decline in profitability (Section IV) and decided, as expected, to reduce application rates.

**Table 21. Reasons for Decreasing Fertilizer Use During 1991/92-1995/96**

| Reasons for Decreasing Quantity of Fertilizer | Frequency of Combined Weighted Responses |
|---|---|
| Increase in the cost of fertilizer | 379 |
| Reduction in fertilizer availability | 183 |
| Decrease in credit availability | 81 |
| Failure in use of fertilizer | 66 |
| Improved soil productivity | 17 |
| Other | 63 |

Source: Calculated from 341 first responses and 208 second responses to Question Q6.2 in FS 1995/96 survey

The availability issue comes out more strongly on the ‘decrease’ side than on the ‘increase’ side. It is the second major reason for decreasing fertilizer use. Perhaps the lesson here is that one needs to build fertilizer distribution networks in a manner that insures their survival, rather than implementing programs with broad geographic coverage that cannot be sustained. Other reasons given to explain declining fertilizer use were reduced availability of fertilizer and fertilizer credit, and lack of success in using the input; all these explanations were mentioned much less frequently, however, than the first two.

### 5.4. Factors Affecting the Use of Fertilizer - Regression Analysis

This section reports the results of wereda-level econometric analysis of factors affecting whether or not fertilizer was used in the wereda, and the average level of fertilizer used per hectare by households in the wereda. A total of 361 weredas were included, based on data collected from the CSA Agricultural Survey and the GMRP Food Security Survey, both covering the 1995/96 crop year. A selectivity model was used to address this issue; methodological details will be reported in a subsequent report. In this section, we focus on the model results and policy implications. As a prelude to the analysis, a large set of potential variables were examined through descriptive correlation analysis. The set of variables explored were:

DOMAIN: Categorical domain-level variables were constructed to examine how average fertilizer use (kg per hectare) in the 361 weredas varied by domain. There are 21 domains covered in the analysis.

AVGRF5: Amount (mm) of rainfall per year in the wereda, based on a five-year historical average.

AVGELEV5: Average elevation of the wereda.

SCMEMB_2: Percent of households in the wereda that are members of a service cooperative. It is hypothesized that this variable may affect households' access to credit, since the large majority of households relying on credit must belong to a farmer group in order to obtain it.

PCLT10P: Percent of households traveling less than 10 km to the nearest marketplace (a proxy for proximity to markets).

CROPDMG: Percent of households reporting crop damage in the wereda. This variable was included due to widespread reports by farmers that fertilizer use is uneconomic in some productive areas because of crop damage by wild animals.

NUMDISTC: Number of fertilizer distribution centers in the zone.

TOTBAN_W: Numbers of development banks and commercial banks in the wereda.

PCFEMHHH: Percent of female-headed households in the wereda.

PCLITHHH: Percent of households in the wereda in which the head is literate.

AVFRMSIZ: Average farm size in the wereda

KNOEXT_1: Percent of households in the wereda that have knowledge of the Government's New Agricultural Extension Program (a proxy for interaction with extension agents).

SORG: Categorical variable taking a value of 1 if the main cereal crop produced in the wereda is sorghum.

TEFF: Categorical variable taking a value of 1 if the main cereal crop produced in the wereda is teff.

WHT: Categorical variable taking a value of 1 if the main cereal crop produced in the wereda is wheat.

PERFA5_1: Percent of households in the wereda receiving food aid in the past 5 years.

TLU: Average amount of livestock owned by households in the wereda.

Basic descriptive statistics on each of these variables is presented in Table 22. There were only 312 valid cases (weredas) for which a full set of data was available.

**Table 22. Descriptive Statistics on Key Variables Hypothesized to Affect Fertilizer Use at the Wereda Level**

| Variable | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|
| AVGRF5 | 1207.33 | 367.39 | | 2100 |
| AVGAELEV5 | 2076.67 | 461.27 | 1000 | 3500 |
| SCMEMB_2 | 32.86 | 34.13 | 0 | 100 |
| PCLT10P | 77.55 | 33.35 | 0 | 100 |
| CROPDMG | 69.8 | 25.39 | 0 | 100 |
| NUMDISTC | 14.5 | 8.59 | 0 | 45 |
| TOTBAN_W | 0.29 | 0.61 | 0 | 3 |
| PCFEMHHH | 0.17 | 0.09 | 0 | 3 |
| PCLITHHH | 0.23 | 0.1316 | 0 | 0.64 |
| AVFRMSIZ | 1.1 | 0.62 | 0.11 | 3.56 |
| KNOEXT_1 | 51.75 | 35.52 | 0 | 100 |
| SORG | 0.34 | 0.3 | 0 | 1 |
| TEFF | 0.48 | 0.58 | 0 | 1 |
| WHT | 0.12 | 0.68 | 0 | 1 |
| PERFQS_1 | 33.42 | 39.01 | 0 | 1 |

Each of these variables was included in the selection model to begin with. A second model was specified after dropping a small number of variables that were shown to be statistically unrelated to wereda-level fertilizer use. The final set of variables estimated in the probit part of the model (i.e. factors determining whether or not households in the wereda used fertilizer) was Di (domain-level categorical variables, with the Tigray domain being incorporated into the constant), AVGRF5, AVGELEV5, AVGFRMSIZ, SCMEMB_2, PCLT10P, CROPDMG, NUMDISTC, TOTBAN_W, AVGFRMSIZ, PCFEMHHH, PCLITHHH, TLU, KNOEXT_1, HASORG, HATEFF, HAWHT, and PERFA5_1. The final set of variables estimated in the continuous portion of the model were: a constant, AVGRF5, AVFRMSIZ, TLU, AVGELEV5, SCMEMB_2, PCLT10P, CROPDMG, NUMDISTC, TOTBAN_W, PCFEMHHH, PCLITHHH, KNOEXT_1, SORG, TEFF, WHT, PERFA5_1.

Of the 312 valid weredas included in the model, there were 101 in which none of the households sampled used fertilizer, and there were 211 weredas in which the total fertilizer use was greater than zero. For the 101 weredas which used no fertilizer, the model predicted correctly in 68% of the cases. For the 211 weredas where fertilizer use was greater than zero, the model predicted correctly in 89% of the cases. The model results are contained in Table 23.

The results indicate that many of the statistically important factors affecting whether or not households in the wereda used fertilizer were related to access to fertilizer, credit, and extension services. The variables representing number of fertilizer distribution centers and distance from markets were both highly significant and positively related to the use of fertilizer in a given wereda. The results also indicate that the number of commercial and development banks in the wereda was moderately important and positively related to the use of fertilizer. Also, the variable proxying for interaction with extension agents positively and significantly increased the probability that fertilizer was used in a given wereda.

The dominance of teff in production patterns was also found to be an important determinant of fertilizer use. This is consistent with information presented earlier that teff area represents a large portion of the total crop area that is fertilized. Sorghum area was found to have a negative but not strongly significant impact on the probability of fertilizer use in a given wereda. Lastly, the percentage of female-headed households was positively related to the probability of fertilizer use. It is not immediately clear why this result would be obtained, and research is continuing to uncover other potentially omitted effects that could be correlated with the prevalence of female-headed households at the wereda level.

Perhaps surprisingly, neither rainfall, elevation, average farm size, nor livestock assets significant affected whether or not fertilizer was used in a given wereda.

Strong domain-level effects also influenced whether or not fertilizer was used in a given wereda. Since Tigray was modeled as the base region, results are presented relative to this region. The results indicate that after controlling for the predetermined variables entered into the probit stage of the model, the following areas had significantly (10% level) less likelihood of using fertilizer, relative to Tigray: North and South Gondar, East and West Gojjam and Agewawi, North Wello and Wag Hamra, South Wello, Oromiya Zone and North Shewa, and East and West Wollega. These results should not be construed that fertilizer use is higher in Tigray than these areas, but rather that *after controlling for other variables entered into the model,* there are unexplained residual differences in fertilizer use between Tigray and these other domains. Two other domains were found to have relatively large number of weredas in which fertilizer was used relative to the base region, after controlling for other factors: these are Hadyia, Gurage and Kembata, as well as East and West Hararge.

**Table 23. Selectivity Model Results with Probit Selection Rule**

| | |
|---|---|
| ML Estimates of Selection Model | |
| Maximum Likelihood Estimates | |
| Dependent variable | KG_HA |
| Number of observations | 312 |
| Iterations completed | 39 |
| Log likelihood function | -1376.715 |
| LHS First 30 estimates are probit equation. | |

*Probit portion*

| Variable | Coefficient | z=b/s.e | significance level |
|---|---|---|---|
| Constant | -3.2457 | -2.564 | 0.01034 |
| D3 | -1.3998 | -1.903 | 0.05709 |
| D4 | -1.3625 | -1.952 | 0.05092 |
| D5 | -1.9344 | -2.061 | 0.03926 |
| D6 | -1.5495 | -2.837 | 0.00455 |
| D7 | -1.5793 | -2.331 | 0.01974 |
| D8 | -0.2198 | -0.316 | 0.75170 |
| D9 | -0.4903 | -0.674 | 0.50022 |
| D10 | -0.48940 | -0.582 | 0.56034 |
| D11 | 0.32098 | 0.625 | 0.53176 |
| D14 | -0.91186 | -1.080 | 0.28012 |
| D15 | -0.30617 | -0.478 | 0.63271 |
| D16 | 0.77125 | 0.881 | 0.37825 |
| D17 | 0.18054 | 0.232 | 0.81689 |
| AVGRF5 | 0.17669E-03 | 0.333 | 0.73899 |
| AVGELEV5 | 0.35819E-03 | 1.171 | 0.24178 |
| AVFRMSIZ | 0.26845E-02 | 1.374 | 0.21956 |
| SCMEMB_2 | 0.38678E-02 | 1.035 | 0.30090 |
| PCLT10P | 0.57848E-02 | 1.786 | 0.07405 |
| CROPDMG | -0.16554E-02 | -0.323 | 0.74632 |
| NUMDISTC | 0.80275E-01 | 2.776 | 0.00551 |
| TOTBAN_W | 0.30329 | 1.498 | 0.13414 |
| PCFEMHHH | 2.6739 | 2.414 | 0.01576 |
| PCLITHHH | 1.7521 | 1.701 | 0.08895 |
| TLU | 0.12893 | 0.421 | 0.67366 |
| KNOEXT_1 | 0.75034E-02 | 2.251 | 0.02437 |
| SORG | -0.34960E-01 | -1.091 | 0.27513 |
| TEFF | 0.16310 | 3.591 | 0.00033 |
| WHT | 0.34364E-01 | 0.996 | 0.31925 |
| PERFA5_1 | -0.49136E-02 | -1.234 | 0.21715 |

**Table 23. (Continued): Selectivity Model Results with Probit Selection Rule**

*Continuous model (using inverse Mills ratio)*

| Variable | Coefficient | z=b/s.e | significance level |
|---|---|---|---|
| Constant | 224.23 | 2.308 | 0.02100 |
| AVGRF5 | -0.527E-01 | -1.638 | 0.10149 |
| AVFRMSIZ | 0.298E-02 | 2.304 | 0.03956 |
| TLU | 0.481E-01 | 1.673 | 0.10896 |
| AVGELEV5 | -0.205E-01 | -0.820 | 0.41229 |
| SCMEMB_2 | -0.188E-01 | 0.297 | 0.94912 |
| PCLT10P | 0.879E-01 | 0.246 | 0.80538 |
| CROPDMG | 0.11890 | 0.283 | 0.77703 |
| NUMDISTC | 0.23220 | 0.158 | 0.87464 |
| TOTBAN_W | 20.525 | 1.485 | 0.13754 |
| PCFEMHHH | -177.63 | -1.323 | 0.18574 |
| PCLITHHH | -5.469 | -0.646 | 0.51809 |
| KNOEXT_1 | 0.12089 | 0.373 | 0.70878 |
| SORG | -3.4263 | -1.404 | 0.16045 |
| TEFF | 1.3334 | 1.047 | 0.29514 |
| WHT | 0.88232 | 0.455 | 0.64929 |
| PERFA5_1 | -0.25159 | -0.778 | 0.43684 |
| Sigma(1) | 95.357 | 21.093 | 0.00000 |
| Rho(1,2) | -0.20489 | -0.665 | 0.50606 |

Many of the variables that were statistically significant in explaining whether or not fertilizer was used in a given wereda become relatively unimportant in explaining the intensity of fertilizer use across weredas (average kg used per hectare in the wereda). There are differences in the set of factors explaining whether or not fertilizer is used and the intensity of fertilizer use. The most important factor explaining the quantity of fertilizer used per hectare is average farm size. As farm size increases, so does the intensity of fertilizer use. This is consistent with results presented earlier showing a strong correlation between farm size and fertilizer dose (kg applied per hectare). This positive association may be due to several factors: larger farms may generate more cash to purchase fertilizer without dependence on credit programs. The credit-related constraints on fertilizer use are underscored by the fact that 80% of fertilizer use in the country is financed on credit. The results also show that the amount of livestock ownership is positively related to fertilizer use intensity. This is most likely because livestock ownership is correlated with draft animal ownership, which is found to be important in facilitating fertilizer use in many countries of Africa (see Dione 1990).

Again, variables such as rainfall, elevation, and membership in service cooperatives were not statistically associated with intensity of fertilizer use. A major conclusion from this wereda-level model is that while we have identified a number of important factors explaining whether or not fertilizer is used in a given wereda, these factors do not appear to have a great effect on the intensity of fertilizer use. We are currently investigating in more detail the determinants of fertilizer use and intensity among households to uncover potentially cost-effective strategies for promoting fertilizer use in Ethiopia.

*Summary of econometric findings:*

- Access to fertilizer, credit, and extension services are of major importance in determining whether fertilizer is used in a given wereda. The following variables were positively associated with weredas where fertilizer was used: number of fertilizer distribution centers, average distance of households from markets, number of commercial and development banks in the wereda, and interaction with extension agents.

- Major teff producing areas were also found to be positively related to fertilizer use at the wereda level. Sorghum area was associated with a negative but not strongly significant impact on the probability of fertilizer use in a given wereda.

- For reasons that are not entirely clear, the percentage of female-headed households was positively related to the probability of fertilizer use.

- Perhaps surprisingly, neither rainfall, elevation, average farm size, nor livestock assets significant affected whether or not fertilizer was used in a given wereda.

- Strong domain-level effects also influenced whether or not fertilizer was used in a given wereda. The highest use of fertilizer by zone, after accounting for other included variables, is Hadyia, Gurage and Kembata, as well as East and West Hararge.

- The most important factor explaining the *quantity* of fertilizer used per hectare is average farm size. As farm size increases, so does the intensity of fertilizer use. Small farms need help in intensifying their use of fertilizer in order to make broad based improvements in farm productivity. Most analysts in Ethiopia have concluded that access to credit and transaction costs of acquiring fertilizer (which tend to be high on a per unit basis because amounts purchased by small farmers are so low) represent key constraints on the use of fertilizer by small farmers.

- The amount of livestock ownership is positively related to fertilizer use intensity.

- Variables such as rainfall, elevation, and membership in service cooperatives were not statistically associated with intensity of fertilizer use.

# 6. SUMMARY AND CONCLUSIONS

## 6.1. Summary

This study has examined how the fertilizer sector evolved since the introduction of the policy reforms in Ethiopia with a view to assessing the implications for enhancing fertilizer use in the country. The results indicate that the full benefit of the reforms have not been realized because of various constraints in the marketing system and institutional issues. Fertilizer retailing is carried out primarily by large distributors/wholesalers with a limited number of sales outlets. As a result, the distribution system at the local level is not as responsive to farmers needs as it could be. Often the market in each wereda, zone or region is controlled by a single firm, thus giving rise to a monopolistic market structure.

At the root of the marketing problem is the inefficient credit system. Because credit was linked (in 1996/97) to particular fertilizer distributors, giving rise to an uneven playing field, firms not favored by the credit system have experienced difficulties in selling their fertilizer stock during a given season. Failure to sell supplies may create serious uncertainty, besides the considerable financial costs created. Since 80% of fertilizer sales are on credit, weaknesses in the credit market not only constrain the growth of fertilizer use and agricultural productivity but also discourage private investment in the agricultural input sector.

Fertilizer credit is administered by local government officials. It is often alleged that there can be a lack of experience, and bureaucratic and sometimes unscrupulous procedures applied in this setting. Suppliers are often nominated by the authorities approving the loan. Administrative measures applied to enforce repayment have exacerbated the marketing problems. The practice of forcing all farmers to pay immediately after harvest can result in a seasonal market oversupply and relatively low grain prices. Harsh penalties on defaulters with genuine problems can induce negative attitudes towards technology adoption and reinforce risk-averse behavior. There are no provisions to protect farmers against the sale of critical assets like oxen in situations of crop failure.

Much of the inadequacies in the credit market are attributed to lack of an effective rural institution for credit delivery. Service cooperatives are too large to ensure repayment through peer pressure. The main reason for the government intervention in the credit market and diversion of valuable time of extension workers to administrative affairs (related to fertilizer loans) can also be attributed to lack of effective credit institutions.

Fertilizer sales do not start until the price for the year is announced by the government. Late announcement of the wholesale price in 1997, for instance, resulted in delays in sales for the belg season. Moreover, sales start long after farmers have sold their grain, not at a time when their cash constraint is less binding.

Another important factor militating against expanded use of fertilizer is the sharp decline in its profitability. The return to fertilizer declined sharply between 1992 and 1997. The VCR for teff, for instance, declined by 55% during this period. The decline amounted to 67% in the case maize and 48% for wheat. The ratio fell below the critical threshold of 2 for 71% of the sites/crops in 1997, compared to none in 1992. The main reason for the declining profitability is the rising fertilizer price relative to output price and inadequate efforts to reduce costs by increasing input and output marketing efficiency.

It is evident that the sharp decline in profitability has not led a proportionate decline in fertilizer consumption. It seems that in the absence of alternative options to restore soil fertility, farmers have no choice but continue to invest on chemical fertilizers, although they know that the return is inadequate to cover the risk involved.

Given the recent decline in fertilizer consumption and the ensuing problem of large carry-over stocks being held by importers, it becomes imperative to examine the determinants of demand. The results of this study have shown that fertilizer use is influenced by variables associated with profitability, financial liquidity, human resources, access to markets, household assets and extension services. A descriptive analysis of the different factors affecting chemical fertilizer use indicated that user households or user weredas tend to allocate more land to some crops like teff (fetches relatively higher prices) and less land to crops such as sorghum (lower prices and more risky production environment). Although the proportion of households using improved seeds, pesticides, and irrigation is generally very small, these practices are more common among fertilizer users than non-users. Users apparently realize that fertilizer is more profitable when used with complementary inputs. Fertilizer adoption is also lower in weredas that faced crop damage and required food aid.

The literacy rate among the users group was 7% higher than among nonusers and the difference was statistically significant, suggesting that literacy has a positive influence on fertilizer adoption. Interaction with extension agents is also higher among fertilizer user groups.

The fact that a lack of resources can be a serious constraint to fertilizer use was confirmed as fertilizer using households on the average own 5 tropical livestock units (TLU), as opposed to 3.65 in the case of non-users. User groups also owned more draft cattle. The difference between users and nonusers was equally pronounced with respect to farm size: farmers who use fertilizer cultivate more land than farmers who did not use fertilizer. The higher the resource base and the larger the size of cultivated land, the higher are the chances that a household will use chemical fertilizer.

Access to credit is among important determinants of fertilizer use. User weredas (as opposed to non users) have better access to banks (as measured by the number of banks in a wereda) and have more households that are members of service cooperatives. A higher rate of adoption was also associated with weredas with more distribution centers in a wereda and better access to market places.

The results of the regression analysis (selection model) confirmed the importance of many of the factors indicated in the descriptive analysis. The statistically significantly factors explaining whether a wereda used or did not use fertilize were: access to fertilizer, credit, and extension services, area under teff cultivation, number of fertilizer distribution centers and distance from markets. The number of distribution centers and area under teff are highly significant explanatory variables.

Many of the variables that were statistically significant in explaining whether or not fertilizer was used in a given wereda become relatively unimportant in explaining variations in the intensity of fertilizer use across weredas (average kg used per hectare in the wereda).

The most important factors explaining the quantity of fertilizer used per hectare are average farm size and the amount of livestock owned. As farm size increases and the number of animals owned goes up, so does the intensity of fertilizer use. Households with adequate productive resources may generate more cash to purchase fertilizer (to buy the input on cash or pay for down payment) or they may be less risk-averse compared to resource-poor farmers.

### 6.2. Implications for Policy

A number of policy implications can be drawn from this study.

First, the reform process needs to include measures that would effectively allow full participation of the private sector at all levels. In particular, measures are required to increase the number of small, private sector, retailers so as to increase the number of distribution centers or retail outlets and make the retail market truly competitive. Fertilizer dealers must also be able to get fertilizer from whichever supplier is offering lower prices and more favorable terms. In this regard, implementing the plan to license wholesalers and retailers by the government, instead of the current practice (each importer and distributor appointing its own wholesaler and retailers or principal-agent relationship), deserves particular attention. This, together with the planned deregulation of wholesale prices (December 31, 1997), is expected to widen and deepen the distribution network at the local level and increase demand. In this regard, the generally positive Kenyan experience with fertilizer market liberalization may provide some useful insights for Ethiopia (see for example, Allgood and Kilugo 1996).

Second, farmers benefit from the reform only when there are as many dealers as possible to take part in the importation and distribution of fertilizer. Any practice that may be viewed as discriminatory could discourage entry or limit the number of participants and discourage investment in storage and other infrastructure by the private sector. National, as well as local government officials must be committed to the principles of free market operations.

Third, the system of credit allocation needs to be improved to allow farmers to purchase fertilizer from retailers of their choice. Supply conditions and terms of sale would remain unresponsive to farmers' interest and liable to corruption if suppliers are nominated by a third party, the local authorities. The introduction of a coupon system, as suggested by NFIA, is expected to help level the playing field and create a favorable environment for a more competitive marketing system.

Fourth, although restructuring service cooperatives has been on the agenda of the government for quite sometime, the progress so far is hardly encouraging. Fertilizer loan disbursement and collection will continue to constrain supplies available from a range of distributors, unless effective cooperative institutions- with the power to exert peer pressure to enforce repayment - are created. Such institutions are also required to allow extension agents to use their time for extension purposes. The Senegalese experience on trying to reform cooperatives may be instructive here -- Senegal experienced many reforms of the input distribution system, but as long as the cooperatives were in some way connected to the government/political system, they never worked as effective credit institutions. What appears to be working now is the creation of a new category of legally-sanctioned organizations -- "Groupement d'Interet Economique." Three or more freely associating (and that is the key --- the free association) individuals can form a mini 'corporation' that has a legal status and can therefore apply for credit. These groups got off to a slow start because of onerous bureaucratic application procedures, but over time they have become very popular and have generally been regarded as successful. The evolving system of decentralized local savings and loan associations in Mali may also be a useful model for Ethiopia (FPH,. 1996).

Fifth, the proportion of weredas without bank branches is considerable (79%). Our analysis has shown a link between fertilizer use and the number of banks operating in a particular wereda. Efforts aimed at increasing the number of bank branches by introducing mobile banking services, rural credit schemes, and involving private banks could have a positive impact on demand. Such measure would also help alleviate the financial constraints of small wholesalers and retailers of fertilizer.

Sixth, complementary inputs such as improved seeds and chemicals and improved farmer management practices are necessary to make fertilizer more profitable and enhance demand at given input and output prices. Measures that improve the effective supply of these inputs are expected to have a positive impact on fertilizer consumption.

Seventh, a favorable impact on fertilizer demand is also expected from measures aimed at building the asset base of poor farmers. Loans for oxen and other animals (with proper consideration for feed and veterinary service) need to be expanded along with the effort to expand fertilizer use. Since fertilizer adoption and intensity of use increases with farm size, further decline and fragmentation of land can adversely affect the intensification process. It is important to note that farm sizes should not decline below a certain minimum level. Ways of consolidating farm sizes may need to be sought in areas where farm sizes are too small to be economically viable.

Eighth, in view of the changing market conditions, variations in the degree of risk faced and differences in the asset base of the farmers, fertilizer recommendation rates need to be flexible. The rates of application need to be lower if fertilizer prices (relative to output prices) are high, the chances of crop failure are high and the asset base of the farmer is weak. Developing several recommendation rates for different categories of farmers and different localities can encourage adoption and ease the debt burden of farmers. Farmers need to be encouraged to use organic fertilizer and practice crop rotation to make up for the reduced application rates of chemical fertilizers. Countries such as Kenya and Malawi have made substantial progress in (1) updating fertilizer (organic and inorganic) trial data, and (2) developing national soil fertility maps and zone/crop specific fertility recommendations which taken into account profitability. Ethiopia might also be able to learn from their experiences (see Allgood and Kilongu 1996; Saka, Green and Ng'ong'ola 1995).

Ninth, crop failure is a major factor that makes investments in fertilizer a risky venture. In the absence of any protection in the form of crop insurance or government guarantees, farmers are forced to sell assets such as oxen, leading to decapitalization. There may not be an easy solution to this problem, but it is high-time that studies on how best to tackle the problem be initiated. In this regard, the contribution of Disaster Prevention and Preparedness Commission (DPPC) need to be looked at.

Last but not least, further research is also required to investigate the determinants of fertilizer use intensity. The results of our regression analysis suggest that variables which influence intensity of use are different from those affecting initial adoption. Both formal and informal surveys at the farm level will be required if we are to improve our knowledge of factors affecting intensity of use and develop models that provide policy makers with information about the relative importance of the different factors.

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**Annex 1. Quantity and Price (nominal) of Fertilizer Distributed to the Peasant Sector (1971 - 1996)**

| | DAP | | | Urea | | | |
|---|---|---|---|---|---|---|---|
| | | Price | | | Price | | |
| Year | (000 Tons) | Unsu/ed | Subsidized | (000 Tons) | Unsu/ed | Subsidized | Total (000 tons) |
| 1971 | 811 | 38.00 | | 136 | 30.00 | | 947 |
| 1972 | 1,744 | 38.00 | | 303 | 32.00 | | 2,047 |
| 1973 | 7,666 | 42.00 | | 710 | 32.00 | | 8,376 |
| 1974 | 12,413 | 44.00 | | 667 | 40.00 | | 13,080 |
| 1975 | 13,209 | 50.00 | | 770 | 50.00 | | 13,979 |
| 1976 | 33636 | 48.00 | | 1,409 | 40.00 | | 35,045 |
| 1977 | 32,535 | 48.00 | | 1,455 | 40.00 | | 33,990 |
| 1978 | 32,217 | 55.00 | | 1,717 | 55.00 | | 33,934 |
| 1979 | 48,277 | 64.00 | | 3,010 | 65.00 | | 51,287 |
| 1980 | 40,742 | 85.00 | | 2,545 | 85.00 | | 43,287 |
| 1981 | 29,668 | 116.30 | | 1,444 | 83.90 | | 31,112 |
| 1982 | 30,255 | 89.00 | | 1,418 | 69.70 | | 31,673 |
| 1983 | 42,047 | 81.40 | | 3,008 | 63.70 | | 45,055 |
| 1984 | 42,147 | 81.40 | | 4,737 | 63.70 | | 46,884 |
| 1985 | 22,296 | 81.40 | | 1,823 | 63.70 | | 24,119 |
| 1986 | 74,345 | 81.40 | | 8,918 | 63.70 | | 83,263 |
| 1987 | 88,336 | 79.80 | | 8,995 | 63.70 | | 97331 |
| 1988 | 85,232 | 81.40 | | 11,441 | 63.70 | | 96,673 |
| 1989 | 99,186 | 96.60 | | 10,115 | 80.90 | | 109,301 |
| 1990 | 92,302 | 88.80 | | 12,808 | 75.10 | | 105,110 |
| 1991 | 79,790 | 91.00 | | 10,489 | 77.30 | | 90,279 |
| 1992 | 135,467 | 107.10 | | 17,191 | 95.30 | | 152658 |
| 1993 | 99,560 | 176.20 | 149.70 | 35,587 | 156.10 | 132.4 | 135,146 |
| 1994 | 176737 | 182.60 | 143.30 | 25,588 | 105.40 | 131.1 | 202325 |
| 1995* | 202311 | 258.00 | 178.00 | 44,411 | 248.00 | 168.0 | 246722 |
| 1996* | 209883 | 256.87 | 200.00 | 43269 | 246.87 | 190 | 253152 |

Source: Compiled from various including Alemayehu Bekele. 1992 *Fertilizer Marketing in Ethiopia: Past and Present*, Paper presented at the Fifth African Fertilizer Trade and Marketing Information Network, Nov. 10-12, 1992, Lome Togo; Mulat Demeke, Fertilizer Procurement, Distribution and Consumption in Ethiopia, in Dejene Aredo and Mulat Demeke (eds), Ethiopian Agriculture: Problems of Transformation, Proceedings of Fourth Annual Conference on the Ethiopian Economy, Addis Ababa, 1995. Sales figures for 1996 and 1997 came from Tibebu Haile, Fertilizer Marketing Operation - 1997 and Demand Forecast for 1998, Paper presented to the Second National Fertilizer Workshop, October 1-3, 1997, Ghion Hotel, Addis Ababa.

* Actual sales as quoted from  Tibebu Haile, Fertilizer Imports, Distribution and Sales 1996, (Paper presented to the National Fertilizer Workshop, Oct. 15 - 18, 1996, Ghion Hotel, Addis Ababa).

**Annex 2. Fertilizer Loan Disbursement (1983-1997) (000' Birr)**

| | Disbursement | | |
|---|---|---|---|
| Year | AIDB | CBE | Total |
| 1983 | 27,835 | - | 27,835 |
| 1984 | 33,866 | - | 33,866 |
| 1985 | 42,134 | - | 42,134 |
| 1986 | 30,106 | 25,462 | 56,178 |
| 1987 | 1,713 | 37,531 | 39,244 |
| 1988 | 21,246 | - | 21,246 |
| 1989 | 35,106 | - | 35,106 |
| 1990 | 72,177 | - | 72,177 |
| 1991 | 44,395 | - | 44,395 |
| 1992 | 35,594 | - | 35,594 |
| 1993 | 14,819 | 2,506 | 17,325 |
| 1994 | 29,030 | 158,287 | 187,317 |
| 1995 | 51,836 | 221,130 | 272,966 |
| 1996* | 56869 | 242096 | 298965 |
| 1997* | 43880 | 185275 | 229155 |

Source: AIDB Research and Planning Division; The Government of Ethiopia, *Integrated Use of Inputs and Distribution Mechanism,* Dec., 1994; and Itana Ayana, Agricultural Inputs and Credit Performance Since 1994, and Plans for 1997, (Paper presented at the National Workshop, 15-18 October, 1996).
* CBE and DBE, Report presented at the Second Annual National Fertilizer Workshop, October 1-3, 1997, Ghion Hotel, Addis Ababa.

## Annex 3. Optimum Rates of Fertilizer Application by Region and By Crop Type

| | No. of trials | NFIU calculation at 1992 prices | | | | Own calculation at 1992 prices | | | | Own calculation at 1997 prices | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | | P2O5 | | N | | P2O5 | | N | | P2O5 | |
| | | Nutrient (kg) | Urea (qt.) | Nutrient (kg) | DAP (qt.) | Nutrient (kg) | Urea (qt.) | Nutrient (kg) | DAP (qt.) | Nutrient (kg) | Urea (qt.) | Nutrient (kg) | DAP (qt.) |
| Teff | | | | | | | | | | | | | |
| Shewa | 537 | 64.00 | 0.91 | 57.00 | 1.24 | 81.27 | 1.10 | 77.81 | 1.69 | 60.66 | 0.86 | 53.37 | 1.16 |
| Gojam | 227 | 57.00 | 0.76 | 56.00 | 1.22 | 73.66 | 0.99 | 72.44 | 1.57 | 53.16 | 0.71 | 52.73 | 1.15 |
| Arsi, Bale | 55 | 45.00 | 0.58 | 47.00 | 1.02 | 58.36 | 0.75 | 61.42 | 1.34 | 41.71 | 0.53 | 43.86 | 0.95 |
| Other | 57 | 12.00 | -0.10 | 42.00 | 0.91 | 69.08 | 0.88 | 73.30 | 1.59 | -1.10 | -0.33 | 35.92 | 0.78 |
| ATC | 876 | 57.00 | 0.79 | 53.00 | 1.15 | 72.14 | 0.97 | 70.37 | 1.53 | 53.43 | 0.73 | 50.25 | 1.09 |
| Wheat | | | | | | | | | | | | | |
| Shewa | 212 | 76.00 | 1.14 | 60.00 | 1.30 | 93.92 | 1.38 | 77.58 | 1.69 | 78.00 | 1.17 | 61.45 | 1.34 |
| Gojam | 42 | 62.00 | 0.95 | 47.00 | 1.02 | 74.06 | 1.13 | 56.89 | 1.24 | 63.14 | 0.96 | 48.22 | 1.05 |
| Arsi, Bale | 252 | 66.00 | 0.82 | 72.00 | 1.57 | 99.86 | 1.29 | 103.57 | 2.25 | 67.34 | 0.83 | 75.10 | 1.63 |
| Other | 33 | 47.00 | 0.58 | 52.00 | 1.13 | 63.71 | 0.82 | 66.72 | 1.45 | 48.25 | 0.59 | 53.87 | 1.17 |
| ATC | 539 | 67.00 | 0.95 | 59.00 | 1.28 | 85.48 | 1.21 | 76.48 | 1.66 | 68.12 | 0.96 | 60.86 | 1.32 |
| Barley | | | | | | | | | | | | | |
| Shewa | 48 | 56.00 | 0.72 | 59.00 | 1.28 | 84.76 | 1.22 | 73.18 | 1.59 | 59.75 | 0.78 | 61.30 | 1.33 |
| Arsi, Bale | 129 | 56.00 | 0.63 | 69.00 | 1.50 | 79.08 | 1.03 | 80.92 | 1.76 | 58.95 | 0.68 | 70.65 | 1.54 |
| Other | 21 | 44.00 | 0.39 | 67.00 | 1.46 | . | . | . | . | | . | . | . |
| ATC | 198 | 59.00 | 0.74 | 64.00 | 1.39 | 83.08 | 1.16 | 75.87 | 1.65 | 61.88 | 0.79 | 65.74 | 1.43 |
| Maize | | | | | | | | | | | | | |
| Shewa | 129 | 56.00 | 0.75 | 55.00 | 1.20 | 69.71 | 0.96 | 65.58 | 1.43 | 43.39 | 0.56 | 45.11 | 0.98 |
| Gojam | 62 | 80.00 | 0.97 | 90.00 | 1.96 | 102.61 | 1.22 | 118.34 | 2.57 | 63.57 | 0.75 | 74.05 | 1.61 |
| Welega, Kefa, Illu | 24 | 90.00 | 1.19 | 90.00 | 1.96 | 600.82 | 9.02 | 475.18 | 10.33 | 153.55 | 1.71 | 191.22 | 4.16 |
| Gamu G., Sidamo | 27 | 46.00 | 0.46 | 64.00 | 1.39 | 62.06 | 0.69 | 77.28 | 1.68 | 30.46 | 0.22 | 51.91 | 1.13 |
| Other | 20 | 55.00 | 1.03 | 19.00 | 0.41 | 113.87 | 0.75 | 202.91 | 4.41 | E. | E | E | E |
| ATC | 262 | 60.00 | 0.76 | 64.00 | 1.39 | 74.84 | 0.97 | 77.09 | 1.68 | 45.26 | 0.55 | 50.98 | 1.11 |
| Sorghum | | | | | | | | | | | | | |
| Shewa | 14 | 24.00 | 0.06 | 54.00 | 1.17 | . | . | . | . | . | . | . | . |
| Hararghe | 12 | 0.00 | -..42 | 49.00 | 1.07 | 104.76 | 0.87 | 165.68 | 3.60 | 29.34 | -0.11 | 87.61 | 1.90 |
| Other | 18 | 39.00 | 0.25 | 70.00 | 1.52 | 71.04 | 0.71 | 97.72 | 2.12 | 48.53 | 0.38 | 78.81 | 1.71 |
| ATC | 44 | 34.00 | 0.17 | 67.00 | 1.46 | 70.36 | 0.56 | 114.33 | 2.49 | 44.69 | 0.27 | 82.84 | 1.80 |

ATC = Across the country

## Annex 4. Comparison of Mean Percent of Households Using Improved Farming Practices for Fertilizer Using and Non-using Weredas

| | % using imrproved seed | | % using manure | | % using pesticides | | % using irrigation | |
|---|---|---|---|---|---|---|---|---|
| KILLIL Region | Wereda doesn't use fert. | Wereda uses fert. | Wereda doesn't use fert. | Wereda uses fert. | Wereda doesn't use fert. | Wereda uses fert | Wereda doesn't use fert. | Wereda uses fert |
| Tigray | | | | | | | | |
| Mean | .00 | .06 | .28 | .30 | .01 | .05 | .04 | .12 |
| Sig dif | | -.05*** | | -.02 | | -.05** | | -.07 |
| Amhara | | | | | | | | |
| Mean | .02 | .03 | .24 | .38 | .03 | .05 | .04 | .07 |
| Sig dif | | -.01 | | -.15** | | -.02 | | -.03 |
| Oromya | | | | | | | | |
| Mean | .01 | .04 | .16 | .31 | .03 | .22 | .04 | .04 |
| Sig dif | | -.03*** | | -.16*** | | -.19*** | | -.005 |
| SNNPR | | | | | | | | |
| Mean | .02 | .03 | .45 | .62 | .05 | .25 | .04 | .01 |
| Sig dif | | -.007 | | -.17* | | -.20*** | | -.03 |
| All four regions | | | | | | | | |
| Mean | .02 | .04 | .27 | .38 | .03 | .17 | .04 | .05 |
| Sig dif | | -.02*** | | .11*** | | -.13*** | | -.01 |

Source: Calculated from CSA 1995/96 meher cropping season data

**ANNEX 5**.

# GRAIN MARKET RESEARCH PROJECT HOUSEHOLD SURVEY (1995/96 CROP YEAR): COMPARABILITY WITH CENTRAL STATISTICAL AUTHORITY AGRICULTURAL SURVEY

Jean Charles Le Vallée

The household-level analysis in this report is derived mainly from two sources. The Grain Market Research Project (GMRP) household survey, implemented in June 1996, and the Central Statistical Authority (CSA) Agricultural Survey, implemented in December 1995. The CSA survey is drawn from a nationally-representative sample of 14,800 households using the CSA sampling frame. The GMRP survey involved 4,218 households included in the CSA survey (hence the GMRP sample is a sub-sample of the CSA survey) and is also nationally-representative with respect to the major agricultural regions of the country, namely Tigray, Oromiya, Amhara, and Southern Regions. The following sub-regions are also considered nationally-representative: Tigray (Tigray); North and South Gonder, East and West Gojam, Agewawi, North and South Wello, Wag Hamra, North Shewa and Oromiya zone (Amhara); East and West Welega, Illubabor and Jima, North, East and West Shewa, Arsi, Bale, Borena, East and West Harerge and Somali (Oromiya); Yem, Keficho, Maji, Shekicho, Bench, North and South Omo, Derashe, Konso, Hadia, Kembata and Gurage, Sidama, Gedeo, Burhi and Amaro (Southern regions). The remaining smaller regions, Afar, Somali, Beni-Shangul and Gumuz, Gambella, Harari, Addis Ababa and Dire Dawa, do not contain sufficient observations for the survey to be considered strictly representative of their region.

The purpose of this annex is to present descriptive statistics on the comparability of key variables contained in the GMRP Household Survey (1995/96 crop year) and the CSA Agricultural Survey (1995/96 crop year). This annex focuses on three key variables in agricultural production: meher crop production, crop area cultivated, and household fertilizer use.

For grain crop production, there are three different national estimates available for the meher season: (a) farmer recall from the GMRP Household Survey; (b) farmer recall from the CSA Agricultural Survey; and (c) crop-cut estimates from the CSA Agricultural Survey (Table 1). Crop cutting involves direct physical measurement within the fields harvested while farmer recall estimates are obtained through surveying farmers after the crops have been harvested (1-2 months after in the case of the CSA Agricultural Survey and 4-5 months afterward in the case of the GMRP survey).

Table 2 shows the correlation coefficients of the three measures of production, with the household being the unit of observation. Strong correlations can be found between the GMRP and CSA farmer recall estimates, particularly for maize, wheat, barley and millet. Correlation coefficients are generally lower between the CSA crop-cut estimates and either the CSA or GMRP farmer recall estimates.

**Table 1. National Meher Grain Production Estimates**

| Source of Estimate | Estimated Production (million metric tons) |
|---|---|
| GMRP Household Survey Farmer Recall | 7.84 |
| CSA Agricultural Survey Farmer Recall | 8.51 |
| CSA Agricultural Survey Crop-cut | 9.27 |

As is the case with the CSA data, it is generally found that the measurement of production from crop cuts result in higher estimates than the estimates from farmer recall. A review of the empirical tests of crop-cut versus farmer recall data collection supports the conclusions that crop-cut estimates of production result in upward biases due to a combination of errors (Murphy et al. 1991, Poate and Casley 1985, Verma et al. 1988). These errors relate to biases resulting from poorly executed techniques (Rozelle 1991), large variances due to heterogeneity of crop conditions within farmer plots (Casley and Kumar 1988), and non-random location of sub-plots and tendencies to harvest crop-cut plots more thoroughly than farmers (Murphy et al. 1991). Verma et al. (1988) found that farmer estimates are closer to actual production (derived from weighing farmers' harvests) than crop-cut estimates. In general, tests of crop-cut estimates in Africa have been found to be overestimated by between 18% and 38% (Verma et al. 1988). Farmer recall was also found to result in a smaller variance in production estimates than crop-cut estimates. On the other hand, crop-cut estimates were found to provide more accurate measurements of crop yield.

Table 3 provides estimate of total cropped area by killil. Using the crop-cut method for estimating area, the results give 8 million hectares nationally for both sample sizes.

ANOVA tests were made on production and area data to see if the sub-sample (GMRP survey) was statistically different of the bigger sample size (CSA survey), in other words, if the sub-sample was representative of the bigger sample if randomly selected. At the national level and also at the regional level (i.e. killil), for all grains, we found no results that showed that these two sample sizes were significantly different at the 0.01 level: thus the sub-sample is representative of the bigger sample.

A comparison of mean household fertilizer use can be found in Table 4. Both sample sizes give very similar results.

**Table 2. Correlation Coefficients of the Three Measures of Production**

| Grain groups | GMRP production (FR | CSA production (FR) | CSA production (CC) |
|---|---|---|---|
| Maize | 1,000** | | |
| Wheat | 2370 222** 636** | 4352 128** 1000 | 4304 1000 |
| Teff | 1,000 1106 228** 702** 1 | 2101 269** 1000 | 2120 1,000 |
| Barley | 1,000 2112 384** 470** | 4105 285** 1,000 | 4044 1000 |
| Sorghum | 1,000 1391 347** 676** | 2637 269** 1,000 | 2613 1000 |
| Millet | 1,000 1852 423** 410** | 3608 333** 1,000 | 3552 1000 |
| Pulses | 1,000 424 416** 622** | 822 284** 1,000 | 806 1000 |
| Oil seeds | 1000 1785 109** 200** | 3354 224** 1,000 | 3322 1000 |
| Number of observations | 666 369** 537** 1000 | 1250 103** 1,000 | 1193 1,000 |

** Correlation is significant at the 0.01 level (2-tailed)

**Table 3. Total Crop Area Compared Between Both Surveys**

| KILLIL | Area (MHa) CSA Survey n=14512 | Area (MHa) FSS Survey n= 3653 |
|---|---|---|
| Tigray | 481 | 484 |
| Afar | 24 | 21 |
| Amhara | 2938 | 3116 |
| Oromiya | 3617 | 3533 |
| Somali | 60 | 58 |
| Benishangul | 95 | 93 |
| SNNPR | 6978 | 7188 |
| Gambela | 101 | 39 |
| Harari | 44 | 45 |
| Addis Ababa | 98 | 96 |
| Dire Dawa | 74 | 59 |
| Total | 7.94 | 8.05 |

**Table 4. Mean Percentage of Households Using Fertilizer by Killil**.

| KILLIL | % hh fert use (CSA survey) | % hh fert use (GMRP Survey) |
|---|---|---|
| Tigray | 45 | 40 |
| Afar | 13 | 3 |
| Amhara | 39 | 36 |
| Oromiya | 49 | 45 |
| Somali | 6 | 6 |
| Benishangul | 23 | 28 |
| SNNPR | 36 | 29 |
| Gambela | 0 | 0 |
| Harari | 81 | 83 |
| Addis Ababa | 97 | 79 |
| Dire Dawa | 34 | 29 |

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# Determinants of fertilizer use on maize in Eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption

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**Abstract**

*Factors influencing the extent and intensity of fertilizer adoption on maize production in Ethiopia were analyzed. A Weighted Endogenous Sampling Maximum Likelihood estimator was used in the specification of a Probit and Tobit fertilizer adoption models. The results have important implications for the formulation of policies and programs targeted to promotion of fertilizer use in small-scale maize production. Those include improved road infrastructure, consideration of weather related crop failure insurance programs, development of drought tolerant cultivars and targeting particular farmer groups.*

## 1. Introduction

Agriculture contributes about 52% of the GDP and 85% of the population is dependent directly or indirectly on agriculture in Ethiopia. While agriculture is growing at 1.6% per annum, the population of the country is growing at 3% and is expected to double by year 2020 (Befekadu and Brehanu, 2000). This indicates the need to increase productivity of agriculture to keep pace with population to ensure adequate supply of food in the future. As a result, the government has embarked on a massive agricultural extension program since 1994/95 to promote the use of improved crop production technologies, a key component of which is chemical fertilizers. However, adoption and intensity of fertilizer application, especially on maize grown by smallholders remained very low despite government efforts to promote its use. Di-Ammonium phosphate (DAP) and urea are the two most important fertilizers that are widely promoted by the extension program. Consumption of the said two fertilizers has dropped significantly between 1995 and 1997 showing a slight increase of only 3% in 1999.

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Maize is one of the major cereals grown in Ethiopia and is the main staple food in many parts of the country. Maize production has slightly increased over the past decade with area expansion being the main source of growth compared to negligible yield gains. Fertilizer has been a major component of improved maize production technologies being promoted by the extension package. It is therefore of critical importance for agricultural research and policy design to better understand the reasons behind the persistence of low fertiliser adoption by farmers in the country. This study makes an attempt to analyse determinants of fertiliser use by small-scale maize producers in Ethiopia.

The analytical framework and empirical models of technology adoption are discussed in section 2. The empirical model and sampling procedures are specified in section 3. Section 4 presents and discusses findings and conclusions and policy implications are drawn in the last section.

## 2. Analytical framework and empirical models of technology adoption

Limited dependant variables models have been widely used in technology adoption studies. The said models are based on the assumption that, in adopting new agricultural technologies, the decision maker (farmer) is assumed to maximize expected utility (expected profit) from using a new technology subject to some constraints (Feder *et al*, 1985). In the case of categorical dependent variables (binomial or multinomial) qualitative choice models of adoption such as the logit and Probit are usually specified. These models are commonly used to analyse situations where the choice problem is whether or not (0-1 value range) to adopt a new technology. The Probit specification has advantages over logit models in small samples. The present study therefore employed a Probit model to examine determinants of farmers' decision to adopt or not adopt fertilisers on maize. The Probit model specification used in this study is given by

$$AF = F(\alpha + \beta x_i) = F(z_i) \tag{1}$$

Where, AF is the discrete adoption choice variable, $F$ is the cumulative probability distribution function, $\beta$ is the vector of parameters, $x$ is the vector of explanatory variables and z is the Z-score of $\beta x$ area under the normal curve.

The expected value of the discrete dependent variable in the Probit model conditional on the explanatory variables is given by

$$E[y/x] = 0[1 - F(\beta' x)] + [F(\beta' x)] = F(\beta') \tag{2}$$

The marginal effect of each explanatory variable on the probability of adoption is:

$$\frac{\partial E[y/x]}{\partial x} = \phi(\beta' x)\beta \tag{3}$$

Where $\phi(.)$ is the standard normal density function.

While the Probit model is adequate for analysing adoption decisions that occur over a discrete range such as yes or no, it does not handle the case of adoption choices that have a continuous value range that is truncated from below. This is the typical case for fertiliser adoption decisions where some farmers apply positive levels of fertiliser while others have zero applications (non-adopters). Intensity of use is a very important aspect of technology adoption because it is not only the choice to use but also how much to apply that often more important. The Tobit model of Tobin (1958) is used to handle truncated distribution dependent choice variables such as level of fertiliser use. This study used the Tobit model specification to analyse determinants of the variation in intensity of fertilizer use by maize farmers as given by

$$\begin{aligned} &AD = x\beta(z) + \sigma f(z) + \varepsilon \\ &\quad AD^*, if \quad AD^* > AD_0 \\ &\quad 0, \quad if \quad AD^* < AD_0 \end{aligned} \tag{4}$$

Where AD is the adoption intensity (level of application), $AD_0$ is the critical value adoption intensity, $x$, $\beta$ and $F(z)$ are as defined in (1). $\sigma$ is the standard error term, $f(x)$ the value of the derivative of the normal curve at a given point (density function).

McDonald and Moffit (1980) showed that the marginal effect of an explanatory variable on the expected value of the censored (truncated distribution) dependent variable is given by

$$\frac{\partial E(AD)}{\partial x_i} = F(z)\beta_i \tag{5}$$

On the other hand, the change in the probability of adoption as the explanatory variable $x_i$ changes is given by:

$$\frac{\partial F(z)}{\partial x_i} = \frac{f(z)\beta_i}{\sigma} \tag{6}$$

And the change in the intensity of adoption among adopters as an explanatory variable changes is given by:

$$\frac{\partial(AD^*)}{\partial x_i} = \beta_i \left[ 1 - \frac{zf(z)}{F(z)} - \frac{f(z)^2}{F(z)^2} \right] \tag{7}$$

Adoption of agricultural technologies is influenced by a number of interrelated components within the decision environment in which farmers operate. For instance, Feder *et al* (1985) identified lack of credit, limited access to information, aversion to risk, inadequate farm size, insufficient human capital, tenure arrangements, absence of adequate farm equipment, chaotic supply of complementary inputs and inappropriate transportation infrastructure as key constraints to rapid adoption of innovations in less developed countries. However, not all factors are equally important in different areas and for farmers with different socio-economic situations.

Socio-economic conditions of farmers are the most cited factors influencing technology adoption. The variables most commonly included in this category are age, education, household size, landholding size, livestock ownership and other factors that indicate the wealth status of farmers. Farmers with bigger land holding size are assumed to have the ability to purchase improved technologies and the capacity to bear risk if the technology fails (Feder *et al*, 1985). This was confirmed in the case of fertilizer by Nkonya *et al* (1997) in Tanzania, Hassan *et al* (1998a) in Kenya and Yohannes *et al* (1990) in Ethiopia whereas; farm size did not matter in Nepal (Shakaya and Flinn, 1985).

The role of education in technology adoption has been extensively discussed in the literature. Education enhances the allocative ability of decision makers by enabling them to think critically and use information sources efficiently. Producers with more education should be aware of more sources of information, and more efficient in evaluating and interpreting information about innovations than those with less education (Wozniak 1984). Education was found to positively affect adoption of improved maize varieties in West shoa, Ethiopia (Alene *et al*, 2000), Tanzania (Nkonya *et al*, 1997) and Nepal (Shakaya and Flinn, 1985).

Some new technologies are relatively labour saving and others are labour using. For those labour-using technologies, like improved varieties of seeds and fertilizer labour availability plays significant role in adoption. Green and Ng'ong'ola (1993) found regular labour to be an important factor that positively influences adoption of fertilizers in Malawi.

On the other hand, age of the household head is an important factor affecting adoption of agricultural technologies. The convention approach to adoption study considers age to be negatively related to adoption based on the assumption that with age farmers become more conservative and less acceptable of new ideas. On the other hand, it is also argued that with age farmers gain more experience and acquaintance with new technologies and hence are expected to have higher ability to use new technologies more efficiently. Some studies found age to be an important determinant of adoption (Hassan *et al*, 1998b) while others didn't (Voh, 1982; Nkonya *et al*, 1997; Chilot *et al*, 1998).

The effect of family size on adoption can be ambiguous. It can hinder the adoption of technologies in areas where farmers are very poor and the financial resources are used for other family commitments with little left for purchase of farm inputs (Voh, 1982; Shakya and Flinn, 1985). On the other hand, it can also be an incentive for adoption of new technologies as more agricultural output is required to meet the family food consumption needs (Yonannes *et al*, 1989) or as more family labour is required for adoption of labour intensive technologies (Hassan *et al*, 1998a).

In addition, adoption of new agricultural technologies depends on a number of institutional factors. The introduction of new technologies creates demand for information useful in making decisions (Wozniak, 1984). Agricultural extension organizations supply useful information about new agricultural technologies. Access to such sources of information can be crucial in adoption of improved varieties (Nkonya *et al*, 1997; Hassan *et al*, 1998b; Chilot *et al*, 1998). Furthermore, risk associated with the adoption of agricultural technologies is another important factor in adoption decisions (Parikh and Bernard, 1988; Yohannes *et al*, 1990; Shiyani *et al*, 2002; Hassan *et al*, 1998).

The studies reviewed above show inconsistent results about the determinants of adoption of new technologies by farmers. In addition, none of the above studies addressed how adoption of fertilizer is affected by farmers' perceptions about the expected rainfall conditions, the perception of farmers about the current prices of fertilizers and the topographic conditions of maize farm plots.

## 3. Specification of the empirical model

In light of the results of previous empirical research, this study considered a number of explanatory variables in modelling the fertiliser adoption behaviour of maize farmers in Ethiopia. Socio-economic factors such as age of the head of the household head, family size, literacy, land holding size and wealth status of the farmer were considered important determinants of adoption. The age of the household head (Age) is measured in years, total land holding size (Land) is measured in Quindi[2] and literacy (Litd) takes a value of one if the farmer is literate and zero otherwise. Household size (Housz) is measured by the number of people living in the household. Income from T'chat[3] (T'chatd) and off farm income (Offincd) were included to reflect the financial ability of the farmer to buy external inputs, both take the value of one if the farmer earns income from the respective activities and zero otherwise. Furthermore, to analyse the effect of the expected profitability of fertilizer adoption, farmers' perception about the current price of fertilizer (Fertpd) was included. This takes value of one if the farmer feels the price is too high and zero otherwise. The topographical nature of land (Slopd), which takes the value of one if the plot is flat and zero otherwise was included. Furthermore, to see the effect of risk associated with the use of fertilizer, farmers' perception about the expected rainfall condition during the production year (Raind) was included. This is measured as one if the farmer perceived the rainfall is good and zero otherwise. Distance of the home of the farmer (Mktd) from the nearby market and the residence of the extension worker (Extd) both measured in minutes of walking distance were selected to capture the impact of institutional constraints on fertilizer adoption in the area.

The above explanatory variables were used to estimate the Probit and Tobit models of fertiliser adoption as specified below

$$\begin{aligned} AF = {} & \beta_0 + \beta_1 Age + \beta_2 Land + \beta_3 Litd + \beta_4 Raind + \beta_5 T'chatd + \beta_6 Offincd + \\ & \beta_7 slopd + \beta_8 Housz + \beta_9 Fertpd + \beta_{10} Mktd + \beta_{11} Extd \end{aligned} \tag{8}$$

Where $AF$ takes the value of one for adopters or zero for non-adopters in the case of the Probit model and is the level of fertiliser used in kg per quindi of land in the Tobit model**.**

## 4. Study area and sampling procedure

The study was conducted in Dadar district, located in the Eastern Hararghe zone of the Oromiya regional state of Ethiopia. Being part of the Ethiopian highlands, the area receives an average annual rainfall of more than 900 mm. Maize and sorghum are the major cereals grown in the area. Maize is the main staple food crop in the district. Being one of the major maize producing

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[2] *Quindi is a local measure of land holding. One hectare is equivalent to eight quindis.*

[3] *T'chat is a perennial shrub grown widely by farmers in East Hararghe. The leaves of the shrub are chewed by humans for stimulation purposes.*

districts in the zone, the area has been included in the government's agricultural extension package since 1996/97. Purposive sampling of a total of 100 farm households was surveyed. Accordingly, 50% the surveyed farmers were from those who have chosen to join the extension package and the remaining 50% were from farmers chosen not to participate in the extension package. In studies involving limited dependent variable models, sometimes the observed sample of the dependent variable is deliberately skewed in favour of one outcome or the other. In estimating models for such studies, the bias in the sample could easily be transmitted to parameter estimates. Manski and Lerman (1997) proposed a Weighted Endogenous Sampling Maximum Likelihood (WESML) method of correcting for this bias. Their estimator requires that the true population proportion $w_1$ and $w_2$ and sample proportions $p_1$ and $p_2$ be known. Then the estimator is obtained by maximizing the weighted likelihood given by

$$Log\ L = \sum_{i}^{n} w_i \log\ F\left(q_i \beta' x_i\right) \tag{9}$$

Where, $w_i = y_i \left(\frac{w_1}{p_1}\right) + \left(1 - y_i\right)\left(\frac{w_2}{p_2}\right)$

The second step involves the correction of the appropriate covariance matrix of the estimator. White's (1982a) robust 'sandwich' estimator for the asymptotic covariance matrix of the quasi-maximum likelihood estimator is given by

$$Est.asy.\text{var}\left(\hat{\beta}\right) = \left[\hat{H}\right]^{-1} \hat{\beta} \left[\hat{H}\right]^{-1} \tag{10}$$

Where, H is the Hessian matrix of the parameters. However, the shortcomings of WESML and choice based sampling estimator are the very large standard error of the parameters that are obtained at the end (Greene, 2000).

The sample size indicated above is used in this study by making modifications following the above procedure. Secondary sources from the district level office of agriculture show that about 25% of the farmers in the area use fertilizer in maize production. So the weighting variable for the estimation of the model is given by

$$w_i = y_1 \left(\frac{0.25}{0.5}\right) + (1 - y_1)\left(\frac{0.75}{0.5}\right) \tag{11}$$

Where, $y_1$ is the value of the dependent variable, which takes values of one and zero in the Probit model. Where as in the Tobit model, $y_1$ is censored at zero for non-adopters and takes continuous values greater than zero for adopters. The correction for the asymptotic covariance matrix of the Probit model is made following the procedure in the second step above. The Tobit model was estimated by using the weighting variable only, as there is no procedure developed so far for the correction of the covariance of the estimated parameters.

## 5. Results and discussion

### 5.1 Probit model results

The explanatory variables of the Probit model reported in Table 1 had the expected sign. Age was negatively and significantly related to adoption of fertilizer suggesting that old farmers are more conservative with respect to fertilizer use than young farmers in the study area. Farmers' expectation of a good rainfall season was positively and significantly associated with fertilizer adoption. Farmers' perception that the current fertilizer price is high was negatively and significantly related to adoption. The removal of fertilizer subsidy in the country since 1997 has increased the actual price of fertilizer by more than 20%.

**Table 1: Estimated results of probit model of adoption of fertilizer**

| Variable | Coefficient | Standard error | P-value | Marginal effect |
|---|---|---|---|---|
| Constant | -0.380 | 0.890 | 0.670 | -0.0820 |
| Age | -0.037* | 0.016 | 0.019 | -0.0079 |
| Land | 0.069 | 0.075 | 0.350 | 0.0150 |
| Litd | 0.400 | 0.390 | 0.270 | 0.0920 |
| Raind | 0.964* | 0.390 | 0.013 | 0.2100 |
| T'chatd | 0.320 | 0.410 | 0.430 | 0.0690 |
| Offincd | 0.210 | 0.390 | 0.600 | 0.0440 |
| Slopd | -0.690 | 0.460 | 0.140 | -0.1500 |
| Housz | 0.110 | 0.082 | 0.180 | 0.0240 |
| Fertpd | -2.080** | 0.700 | 0.003 | -0.4500 |
| Mktd | -0.007 | 0.006 | 0.890 | -0.0002 |
| Extd | -0.008 | 0.013 | 0.550 | -0.0017 |

Restricted log likelihood -67.74464 ; Chi-Square 63.66396 ; ** Significant at 1% ; * Significant at 5%

The marginal effect values of the Probit model in Table 1 show the change in the probability of adoption of fertilizer for each additional unit increase in independent variables. Farmers with the perception of good rainfall conditions had 21% higher probability of adoption than farmers who perceived a bad season. Farmers who thought that the price of fertilizer was high had 45% less probability of adoption. The probability of adoption decreases by 0.79% for every year of age. The probability of adopting fertilizer by farmers cultivating medium to steep maize plots was 15% higher than for farmers cultivating flat maize plots.

### 5.2 Tobit model results

The results of the Tobit model reported in Table 2 show that all the variables have the expected sign. The marginal effects show that for each additional year of age, the use of fertilizer declines by 0.87kg/ha for the entire sample and by 1.6kg/ha for adopters. Positive expectation about the rainfall condition increased the use of fertilizer by 22.07kg/ha and 41.92kg/ha for the entire sample and among adopters, respectively. The perception of high price reduced the use of fertilizer by 46.2kg/ha and 87.79kg/ha for the entire sample and for adopters, respectively. Farmers planting maize on flat land tend to use about 29 kg of fertilizer less than those planting on slopes. This can be attributed to the fact that farmers cultivating flat land experience less leaching of fertilizer compared to steep slopes land.

**Table 2: The Tobit model of fertilizer adoption in Dadar district**

| Variable | Coefficient | Standard error | P-value | Total change $\frac{\partial E(AD)}{\partial x_i}$ | Change in probability $\frac{\partial F(z)}{\partial x_i}$ | Change among adopters $\frac{\partial (AD)}{\partial x_i}$ |
|---|---|---|---|---|---|---|
| Constant | 28.86 | 107.79 | 0.789 | | | |
| Age | -5.18* | 2.29 | 0.024 | -0.87 | -0.014 | -1.600 |
| Land | 9.28 | 8.27 | 0.262 | 1.56 | 0.026 | 2.970 |
| Litd | 51.08 | 47.52 | 0.282 | 8.61 | 0.142 | 16.350 |
| Raind | 130.99** | 48.04 | 0.006 | 22.07 | 0.364 | 41.920 |
| T'chatd | 31.06 | 49.45 | 0.529 | 5.23 | 0.086 | 9.940 |
| Offincd | 21.94 | 49.44 | 0.657 | 3.69 | 0.061 | 7.020 |
| Slopd | -91.18 | 59.36 | 0.125 | -15.36 | -0.254 | -29.180 |
| Housz | 14.31 | 9.77 | 0.143 | 2.41 | 0.039 | 4.580 |
| Fertpd | -274.35** | 93.97 | 0.004 | -46.23 | -0.763 | -87.790 |
| Mktd | -0.019 | 0.59 | 0.975 | -0.03 | -0.00005 | -0.006 |
| Extd | -0.930 | 1.68 | 0.579 | 0.16 | -0.0025 | -0.290 |

Log likelihood function -186.95; $\sigma$ = 141.71; ** Significant at 1%; * Significant at 5%; z = -0.976;
Censored observations = 50 ; Uncensored observations = 50; $F(z)$=0.76 ; $f(z)$=0.394

## 6. Conclusions and policy implications

Fertilizer is considered the most important input for the achievement of increased agricultural productivity and food security status of farm households in Ethiopia. However, fertilizer adoption remains very low, especially among small-scale farmers in the country. The results of this study showed that the age of the farmer, farmers' expectations of rainfall conditions and farmers' perception of the price of fertilizer significantly affect the use and intensity of adoption of fertilizer in the study area.

In situations where the expected rainfall (weather) condition is bad, farmers are unwilling to use fertilizer. This is because farmers are not insured against losses as a result of bad weather and forced to pay the cost of fertilizer they received on credit. Due to the fact that crop loss insurance schemes are non-existent in countries like Ethiopia, agricultural research has to focus on the development of moisture stress tolerant and early maturing varieties. In addition, the expansion of small-scale irrigation projects in rural areas can help overcome the adverse effects of rainfall shortage experienced by most parts of the country. On the other hand, depending on the expected rainfall condition during a particular year fertilizer demand may be high or low. Thus, agricultural extension and suppliers of agricultural inputs (public or private) should adjust the price and the services they provide accordingly.

Increased fertilizer prices and the concomitant decrease in output prices have been the most important factors associated with use of new agricultural technologies in Ethiopia recently. Part of the increase in fertilizer prices to farmers is the increased transportation cost for the movement of fertilizer from the central market. Due to poor road conditions, running costs for transport operators is very high. The development of rural roads reduces the transaction cost associated with acquisition of farm inputs and sale of farm products. This enables farmers to buy farm inputs at lower prices and sell their produce at competitive prices. More effort in expanding roads in rural areas is therefore needed.

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# Factors Affecting Adoption of Improved Maize Seeds and Use of Inorganic Fertilizer for Maize Production in the Intermediate and Lowland Zones of Tanzania

**Aloyce R.M. Kaliba, Hugo Verkuijl, and Wilfred Mwangi**

ABSTRACT

This paper examines factors influencing the adoption of improved maize seeds and the use of inorganic fertilizer for maize production by farmers in the intermediate and lowland zones of Tanzania. The results indicate that availability of extension services, on-farm field trials, variety characteristics and rainfall were the most important factors that influenced the extent of adopting improved maize seeds and the use of inorganic fertilizer for maize production. Farmers preferred those varieties which minimize field loss rather than maximizing yields. Future research and extension policies should emphasize farmer participation in the research process and on-farm field trials for varietal evaluation and demonstration purposes.

**Key Words:** *Adoption, agroecological zones, improved maize seeds, new technology, Tanzania.*

Farmers' adoption of a new technology, such as improved maize seeds, is a choice between traditional and new technology. Farmers' decision to adopt or not to adopt is usually based on the profitability and risk associated with the new technology. Before adoption, farmers have to be assured of the expected marginal gains and associated risk. The farmers' concern with marginal gains and risk in turn affects the adoption of the new technology. Most adoption studies under small holder production systems show that farmers are risk averse and follow a technological ladder in the adoption process. They will first adopt simple components and then move to complex ones, and from cheaper to more costly technologies. The process allows farmers to evaluate available alternatives to avoid incurring unnecessary costs. Experimentation before adoption enables farmers to choose technologies that are less variable in outcomes and those that do not disrupt but enhance existing farming systems (CIMMYT, 1988).

Output variability is a major source of production risk under subsistence agriculture, especially when production depends solely on

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rainfall. Output variability affects both marginal gains and total farm output that influence food security at the household level. Food security is the most important priority for most subsistence farmers. Farmers prefer improved maize seeds that are stable in yield at different level of moisture availability (Moshi *et al.*). Farmers avoid improved maize seeds that are highly variable in terms of yields as they pose food insecurity to households. Risk-management strategies (reduction of yield variability) will therefore impact which variety to adopt or not to adopt. At the household level, risk-management strategies, and thus adoption choices, are then formulated based on socio-economic circumstances faced by the farmer and the characteristics of the technology (CIMMYT, 1993).

This study aims at determining factors that influence the adoption of improved maize seeds and uses of inorganic fertilizer for maize production by farmers in the intermediate and lowland zones of Tanzania. The objective is to generate first-hand information to be used by stakeholders involved in research, extension, and agricultural policy development in Tanzania. The limitation of this study, as with most studies using single-visit cross-sectional surveys, precludes inclusion of some economic factors likely to influence the adoption process. Factors such as price of input and output, taste and preference of individual households, and input distribution and availability may enhance or limit the adoption and diffusion process of the technologies. These variables are not included in the model, not because of their insignificance but because of their unavailability at the household level. However, their absence does not undermine specific policy implications that can be deduced from this analysis.

The plan of the paper is as follows. Section 1 introduces the idea of adoption processes under subsistence agriculture. Major factors associated with the choice of technology are discussed. Section 2 presents a historical background of maize research program in Tanzania. Section 3 discusses available theoretical models that are used in adoption studies and their limitations. Section 4 presents the theoretical model and econometric procedure used to estimate factors influencing choice of technologies by farmers. The section also discusses the variables included in the model, focusing on the rationale and their expected marginal effect on the adoption process. Section 5 reviews the source of data and sampling procedures. Section 6 discusses results of the study and Section 7 summarizes the paper and presents recommendations arising from this study.

## Background

Maize is the major cereal consumed in Tanzania. It is estimated that the annual per-capita consumption of maize in Tanzania is 112.5 kg. National maize consumption is estimated to be three million tons per year. Maize contributes 60 percent of dietary calories to Tanzanian consumers (FSD, 1992, 1996). The cereal also contributes more than 50 percent of utilizable protein (Due). The crop is cultivated on an average of two million hectares, or about 45 percent of the cultivated area in Tanzania. Realizing the importance of the maize crop in Tanzania, the government has been committing human and financial resources to develop the industry. Research and extension efforts in maize started in 1960. The breeding efforts in the 1960s resulted in the release of Ukiriguru Composite A (UCA) and Ilonga Composite White (ICW).

Between 1973 and 1975, Tanzania experienced a severe food shortage due to drought and the villagization campaign that displaced farmers. The food crisis prompted the nation to launch several campaigns such as 'agriculture for survival' (*kilimo cha kufa na kupona*) with the objective of food self-sufficiency. The country also launched a maize project in 1974 with the assistance of the U.S. Agency for International Development (USAID). Its objective was to promote maize production in pursuit of food self-sufficiency. In the research frontier, a National Maize Research Program (NMRP) was launched with the broad objective of developing cultivars suitable for three major varietal recommendations ecological zones: (i) *high-altitude zone* (with elevation of above 1500 masl), with a growing period of 6–8 months; (ii) *intermediate zone* (900–1500 masl), with 4–5 months growing period, and (iii) *low-altitude zone* (0–900 masl), with 3–4 months growing period.

To date, several breeding populations have been developed and are being improved through recurrent selection for specific traits (Moshi *et al.*). Since 1974, two hybrids and six open-pollinated varieties (OPVs) have been released. In 1976, Tuxpeno was released for the lowland areas. Hybrids H6302 and H614, suitable for the highlands, were released in 1977 and 1978, respectively. In November 1983, three OPVs—Kito, Kilima, and Staha—were released. Staha is characterized by its tolerance to maize streak virus (MSV) disease, whereas Kilima was recommended for the intermediate zone. Kito is an early maturing variety adapted to both low and intermediate zones. In 1987 two open-pollinated varieties, TMV1 and TMV2 were released. TMV1 is white flint streak resistant and has intermediate maturity. It is recommended for the lowland and intermediate zones. TMV2 is also white flint, and is recommended for the highlands.

In 1994, the NMRP released versions of Kilima, UCA, Kito, and Katumani that are resistant to MSV diseases. They are Kilima-ST, UCA-ST, Kito-ST, and Katumani-ST. Around the same time two foreign seed companies, Cargill and Pannar, introduced/released seven hybrids for commercial use by the farmers in the country. Since the 1960s no follow-up study has been conducted to assess the adoption process of all these varieties. This paper examines the factors affecting adoption of improved maize seeds and use of inorganic fertilizer for maize production in the intermediate and lowland zones.

## Procedure For Estimation Of Adoption

Feder *et al.* define *adoption* as the degree to which a new technology is used in long-run equilibrium when farmers have complete information about the technology and its potential. Therefore, adoption at the farm level indicates farmers' decisions to use a new technology in the production process. The commonly used procedure to assess adoption at the farm level is a binary variable (adoption of improved maize seed = 1, non-adoption = 0). The intensity of adoption is analyzed using a continuous dependent variable (e.g., hectares under improved maize varieties).

Most of the technical agricultural innovations are in the form of a technology package. The choice to adopt a technical component entails adoption of one or more of the complementary components. Adoption of several components will require the estimation of two or more adoption equations. The econometric procedure then depends on the assumption about the adoption process. Smale, Just, and Leather indicate that the decision to adopt improved seeds and fertilizer is made simultaneously. In order to correct for the simultaneity bias, the adoption equations have to be solved using the two-stage estimation procedure (Amemiya, Nelson and Olson; Yaron, Dinar and Voet; Kimhi). Due to technical difficulties associated with obtaining consistent estimates of the covariance matrix of a two-stage procedure, Goodwin proposed the use of parametric bootstrapping as illustrated by White. The procedure provides a direct and analytically simplified approach to simultaneous models with censored distributions (Nkonya, Schroeder and Norman). In this approach, a large number of pseudo samples of size N are selected from the original data with replacement. Each pseudo sample is estimated separately as a single equation. The distribution of each estimated coefficient from pseudo samples is then used to calculate the value of the required parameter as the mean of the distribution. As Goodwin shows, the estimated parameters are unbiased, consistent and efficient as compared with maximum likelihood results.

Other studies by Byerlee and Hesse de Polanco; Norman *et al.*; and Kaliba, Featherstone, and Norman have shown that small-scale farmers in low-income countries adopt innovations in a step-wise fashion. Farmers will decide to adopt the major technical innovation from the package (e.g., improved maize seeds) and choose to adopt other complementary components (e.g., fertilizer or pesticides) as they learn by doing. The second adoption equation then constitutes a sub-sample of the major component adopters. Hall identified the first and the second adoption equation as selection and regression equations. When the selection and regression equations are identified by probit and ordinary least square (OLS) models, Green and Saha, Love, Schwart suggest the use of sample selection procedure or the Heckman's two-stage procedure to solve the two equations.

## Model Estimated

This paper determined factors affecting allocation of land to improved maize varieties and incidence of fertilizer use for maize production in two agroecological zones. The basic assumption is that a farmer first tests and then adopts improved seeds by allocating part of the land to improved maize, and then decides to use fertilizer. Thus, land allocation to improved maize is independent of fertilizer use, but use of fertilizer is conditional on land allocation to improved maize, which can be specified as follows:

$$
\begin{aligned}
(1)\quad & Y_1 = XB + \mu_1 \\
& Y_1 > 0 && \text{if } XB + \mu_1 > 0 \\
& Y_1 = 0 && \text{if } XB + \mu_1 = 0 \\
& Y_2 = XB + \mu_2 && \text{if } Y_1 > 0 \\
& Y_2 = \text{unobserved} && \text{if } Y_1 = 0 \\
& \quad \operatorname{var}(\mu_1) = \sigma^2 && \operatorname{var}(\mu_2) = 1 \\
& \operatorname{Corr}(\mu_1, \mu_2) = \rho
\end{aligned}
$$

where $Y_1$ is the proportion of total maize area allocated to improved maize seeds, $Y_2$ is the incidence of fertilizer use ($Y_2 = 1$ if used fertilizer; 0 otherwise), X's are exogenous variables affecting adoption, B are parameters to be estimated, $\sigma_1^2$ is the standard error of the estimate, $\mu_1$ and $\mu_2$ are random error terms, which are correlated ($\rho$).

The tobit (Tobin) and probit (McFadden) models were used to test factors influencing adoption of improved maize varieties (PLAND) and use of inorganic fertilizer (FERT), respectively. The predicted values of PLAND for $Y_1 > 0$, i.e., (PLAND*) were recovered from the procedure and included as an independent variable in the FERT equation. The FERT equation was estimated using bootstrapping technique explained above. In the estimation process, one thousand pseudo-samples of equal observation were drawn from the FERT equation with replacement. Each drawn sample was estimated separately as a probit model. The distributions of estimated coefficients from one thousand equations was used to calculate the value of required parameters as the means of the distributions. The models can further be specified as:

$$
\begin{aligned}
(2)\quad & \text{PLAND} \\
& \quad = \beta_0 + \beta_1\text{AGE} + \beta_2\text{LAB} + \beta_3\text{EDVC} \\
& \qquad + \beta_4\text{WID} + \beta_5\text{EXI} + \beta_6\text{YRATIO} \\
& \qquad + \beta_7\text{VA1} + \beta_8\text{VA2} + \beta_9\text{AEZ1} \\
& \qquad + \beta_{10}\text{AEZ2} + \beta_{11}\text{LOW} + \mu_1 \\
& \text{FERT} \\
& \quad = \theta_0 + \theta_1\text{PLAND*} + \theta_2\text{AGE} + \theta_3\text{LAB} \\
& \qquad + \theta_4\text{EDVC} + \theta_5\text{WID} + \theta_6\text{EXI} \\
& \qquad + \theta_7\text{YRATIO} + \theta_8\text{VA1} + \theta_9\text{VA2} \\
& \qquad + \theta_{10}\text{AEZ1} + \theta_{11}\text{AEZ2} + \theta_{12}\text{LOW} + \mu_{21}
\end{aligned}
$$

where:

PLAND = proportion of maize area allocated for improved maize varieties (average of 1992–1994)

FERT = use fertilizer (FERT = 1 if used fertilizer; 0 otherwise) for the same period

$\beta_1$ and $\theta_1$ = parameters to be estimated

AGE = household head age in years

LAB = number of adults in the household (15 years and above)

EDVC = education level of household head in years

WID = wealth index

EXI = index of extension services

YRATIO = yield of improved varieties/yield of local varieties (average of 1992–94)

VA1–3 = group of improved maize varieties (VA1 = 1 if the farmer grows the variety in group 1; VA1 = 0 otherwise)

AEZ1–2 = low and medium rainfall areas (AEZ1 = 1 if a farmer is in the low rainfall area, AEZ1 = 0 otherwise)

LOW = lowland zone (LOW = 1 if the farmer is in the lowlands zone, 0 otherwise).

The high rainfall and intermediate zone dummies were not included in the models to avoid multicollinearity (Griffiths *et al.*; Green). From the literature, factors influencing adoption of new agricultural innovation based on profitability of the technology and risk-management strategies of the farmers can be divided into four major categories: (i) farmers' resource endowment-human and physical (Rogers; Feder and Slade; Feder, Just, Zilberman; Rahm and Huffman; Huffman and Lange; Heisey and Mwangi), (ii) external support systems such as marketing systems, infrastructure, credit, and extension; (iii) characteristics of the technology (Ockwell, Adesina and Zinnah, Misra, Carley and Fletcher), and (iv) the geographical characteristics.

Human endowment factors enable potential adopters to understand and evaluate new information, thus affecting both adoption and diffusion of new technologies (Schultz, 1964, 1975). The variable used to capture human endowment is education (Wharton; Huffman; Rahm and Huffman; Goodwin and Schroeder) and experience of the farmer (Feder; Bhattacharyya *et al.*). Exposure to education will increase the ability of farmers to obtain, process, and use information relevant to the adoption of improved maize variety. Hence this exposure will increase farmers' probability to adopt improved maize technologies. In most adoption studies conducted in low-income countries, the age of the farmer is commonly used to reflect experience. Farmers' age can generate or erode confidence; hence they become more/less risk averse to new technology. It is therefore hypothesised that a farmer's age can increase or decrease the probability of adopting the improved maize technologies. Another factor discussed in literature is the gender of the household head. This affects adoption by influencing the choice of innovation from the recommended technical packages. Female-headed households are usually poor and their choice of innovations to adopt may differ from that of male-headed households. In this study, gender of household head is not included in the analysis because there were few female-headed household in the sample (1 percent). In Tanzania, female-headed households are not very common. To capture them needs a gender specific study with purposeful sampling. Availability of labor is another factor that influences adoption of new technologies. Households with more adults will be able to provide the necessary labor that might be required by improved maize technologies. Thus, labor is expected to increase the probability of adopting the improved maize technologies.

Putler and Zilberman underscored the importance of physical capital endowment in the adoption process. Farm size or cultivated land, livestock and farm implements owned often represent the physical capital endowment (Feder and O'Mara; Feder, Just and Zilberman; Rahm and Huffman; Shapiro; Nkonya, Schroeder and Norman; Kaliba, Featherstone and Norman). Holland suggested establishing a wealth index (WID) to represent the physical capital endowment. The wealth index is calculated by aggregating the average number of livestock units, hand hoes, axes, cutting equipment owned and land cultivated for the past three years. Wealthier farmers may have the means to purchase parts of the improved maize technology; hence it is expected to be positively associated with the decision to adopt improved maize technology package. However, due to differences in risk-management strategies used by relatively poor and rich farmers, the sign on the wealth index may be prior indeterminate. Other studies (see Kaliba, Featherstone and Norman) show that farmers with limited resources use input intensification as a mean of increasing total farm production and managing risk, while relatively rich farmers with alternative resources use diversification and extensive production to achieve both objectives. When the technologies are input intensive, the wealth index may have negative impact on the adoption of the technologies.

External influences that affect adoption include institutional support systems such as marketing facilities, credit, and research and extension services (Feder). Credit was not included as a factor explaining the adoption of maize technologies because very few farmers in the study area used credit to purchase farm inputs. Holland suggested establishing an extension index (EXT) to represent the flow of information from the extension service to farmers. The number of recommendations the farmer was aware of from the extension technology package consisting of six recommendations—improved seeds, row planting, fertilizer application, ox-ploughing, field pests and disease control—was used to calculate the extension index. The Ministry of Agriculture and Cooperatives (MAC) is the major source of agricultural information in the study area. Hence, it is hypothesized that contacts with extension workers will increase a farmer's likelihood of adopting improved maize technologies.

As stated before, risk and risk management are important factors that affect adoption by small-scale farmers (Saha, Love and Schwart; Kaliba, Featherstone and Norman). The embodied technology characteristics will determine the level of profit and risk to be faced by the farmer and thus a choice between available alternatives. As there is no difference in producer price between IMVs and local varieties of seeds, the difference in yield will determine the marginal gain of adopting IMVs. The yield ratio between IMVs and local varieties can therefore represent profitability of the varieties. A larger value of yield ratio means that the farmer is more likely to get a high profit margin than farmers with a low value-of-yield ratio. The basic assumption is that high yielding varieties will be preferred by farmers over low yielding varieties.

Time to maturity of improved seeds is a major factor correlated to risk management under subsistence agriculture. Short maturing varieties usually yield less than long maturing varieties but can escape moisture stress easier than long maturing varieties. Therefore, time of maturity can have negative or positive impact on the adoption of improved maize seeds depending on the farmer's attitude toward risk. The IMVs found in the field were therefore grouped according to months to maturity. Group 1 (VA1), were long maturing varieties (6–8 months) and included UCA and Kilima varieties. Group 2 (VA2), were intermediate maturing varieties (4–5 months) and included TMV-1, Staha, Tuxpeno and ICW varieties. The short maturing varieties (3 months) included Kito and Katumaini varieties and were in Group 3 (VA3). Farmers growing Group 3 varieties were assumed to be more risk averse.

Geographical characteristics influence the general performance of many agricultural innovations. Climate, especially rainfall, is a major factor affecting agricultural production of small-scale farmers in low-income countries. High rainfall secures farmers the precipitation needed for improved maize technologies, and thus is expected to have a positive impact on adoption of improved maize technologies. The agroecological zones can positively or negatively influence a farmer's decision to adopt an improved maize technology package.

## Source of Data

The results presented in this paper are part of a national study conducted to assess the impact of maize research and development in the seven administrative zones of Tanzania. About 1000 farmers were interviewed nationwide. This paper aggregates the survey results from Central, Eastern, Southern, and Western zones which accounted for 30 percent of the national sample households. At zonal level, districts were purposively selected and clustered by the amount of precipitation and altitude. At district level, villages were purposively selected according to maize production and accessibility. From each village, between 6 to 18 farmers were randomly sampled from the register

**Table 1.** Summary Statistics of Variables Used in the Tobit and Probit Analysis

| | | Adopters | | Non-adopters | |
|---|---|---|---|---|---|
| Variable | Sample | IMVs | Fertilizer | IMVs | Fertilizer |
| Age of household head (Years) | 44.6 | 44.1 | 42.8 | 45.3 | 45.1 |
| | (13.0) | (12.6) | (12.9) | (13.4) | (13.0) |
| Number of adults in the household | 4.9 | 4.8 | 4.4 | 5.1 | 5.1 |
| | (4.5) | (3.7) | (2.7) | (4.7) | (4.9) |
| Education of household head (years) | 4.8 | 5.3 | 5.1 | 4.2 | 4.8 |
| | (3.0) | (2.8) | (3.1) | (3.1) | (3.0) |
| Wealth index | 3.9 | 3.9 | 3.5 | 4.0 | 4.1 |
| | (5.9) | (6.4) | (2.7) | (4.6) | (6.6) |
| Farmers growing Group 1 varieties (%) | 9.21 | 16.36 | 10.29 | — | — |
| Farmers growing Group 2 varieties (%) | 23.89 | 42.42 | 30.88 | — | — |
| Farmers growing Group 3 varieties (%) | 32.76 | 58.18 | 29.41 | — | — |
| Farmers in agroecological Zone 1 (%) | 43.00 | 27.27 | 33.82 | 63.21 | 45.78 |
| Farmers in agroecological Zone 2 (%) | 33.11 | 45.46 | 36.77 | 17.20 | 32.00 |

Numbers in brackets are standard deviation
IMVs = improved maize varieties
Agroecological Zone 1 = Low rainfall (<600 mm annually)
Agroecological Zone 2 = intermediate rainfall (600–1000 mm annually)
Agroecological Zone 3 = high rainfall (>1000 mm annually)

of households. To increase data validity and reliability farmers were interviewed by researchers and experienced extension officers using a structured questionnaire developed by a panel of the zonal farming systems' research economists from the Ministry of Agriculture, Sokoine University of Agriculture (SUA), International Maize and Wheat Improvement Center (CIMMYT), and the South African Center for Cooperation in Agricultural Research and Natural Resources (SACCAR), and the national maize breeders and agronomists. The interviews were conducted between June and November 1994. This study does not include varieties released by Cargill and Pannar companies, which released their first varieties when the study was in progress.

Characteristics of sampled households, adopters and non-adopters, used in the analysis of improved maize varieties and fertilizer are presented in Table 1. There were no significant differences between adopters and non-adopters for the household head characteristics, except for the level of education and extension index. The available labor averaged five persons per household and the level of education was five years on average. However, the level of education of adopters was above the sample mean while that of non-adopters was below the sample mean. Adopters of improved maize varieties and fertilizer knew 60 percent and 50 percent of the technical components of the extension package, respectively. Non-adopters of both technologies were aware of 40 percent and 50 percent of the package components, respectively. About 57 percent and 43 percent of respondents were interviewed from the lowland and intermediate zones, respectively. In the sample, 56 percent of respondents adopted at least one improved maize variety and 23 percent used inorganic fertilizer for maize production. The proportion of land for improved maize varieties relative to the total acreage for maize production averaged 40 percent. Adopters of IMVs allocated 70 percent of the maize field to improved seeds while fertilizer adopters allocated about 50 percent of the field. Most farmers grew varieties in Group 3 (VA3) (33 percent). Nine and 24 percent of the respondents grew Group 1 (VA1) and 2 (VA2) varieties, respectively. About 58, 42 and 16 percent of IMVs adopters grew varieties in group VA3, VA2, and VA1, respectively. IMVs and inorganic fertilizer were adopted by 27 percent and 29 percent of respondents in the high rain-

**Table 2.** Average Area and Yield of Local and Improved (1992/94)[a]

| | | | Yield | | | |
|---|---|---|---|---|---|---|
| | | | With Fertilizer | | Without Fertilizer | |
| Agroecological Zones | Variety | Area | Mean | STD | Mean | STD |
| High rainfall | Local | 3.30 | — | — | 2.48 | 1.85 (115) |
| | IMVs | 6.85 | 6.33 | 7.09 (112) | 5.07 | 4.19 (83) |
| Intermediate rainfall | Local | 3.48 | — | — | 2.55 | 2.01 (84) |
| | IMVs | 7.83 | 5.38 | 5.89 (109) | 5.22 | 3.28 (63) |
| Low rainfall | Local | 6.85 | — | — | 3.30 | 3.34 (101) |
| | IMVs | 16.92 | 5.68 | 9.49 (167) | 3.67 | 3.48 (95) |

[a] Area is estimated in terms of acres and yield in terms of bags. One bag is equivalent to 90 kg
IMVs = improved maize varieties
Local = local varieties
STD = standard deviation
Numbers in brackets are coefficient of variation ((STD/Mean) · 100)

fall areas, respectively; 46 percent and 37 percent in the medium rainfall areas, respectively; 16 percent and 11 percent in the low rainfall areas, respectively.

Area and yield of local and IMVs by agroecological zones are presented in Table 2. The area planted in improved varieties was difficult to establish, because farmers tend to plant more than two improved varieties in one plot. The data collected were therefore total acreage allocated to all IMVs grown by the farmer and their characteristics. The results show that the area allocated to IMVs was more than twice as much as the area allocated to local varieties. Yields of IMVs with and without fertilizer were also more that two times higher than yields of local varieties. However, yield variability increased with the use of IMVs and fertilizer. The coefficient of yield variability for IMVs with fertilizer ranged between 109 to 167 percent for all agroecological zone. For IMVs grown without fertilizer and local varieties, the ranges were 82 to 94 and 83 to 101 percent respectively. The coefficient of variability for IMVs without fertilizer fall within the range of local varieties' coefficient of variability.

## Results and Discussion

### *Land Allocation To Improved Maize Varieties*

Table 3 shows the results from the Tobit model explaining the extent of land allocation to IMVs by respondents. In the Table, $\delta EY/\delta X_i$ shows the effect of a unit change of an explanatory variable on the expected value of the depended variable, $\delta EY^*/\delta X_i$ shows the proportionate change in the extent of adoption among adopters with the unit change of an explanatory variable, and $\delta F(z)/\delta X_i$ shows the change in probability of adoption among non adopters given a unit change in an explanatory variable (McDonald and Moffit; Roncek).

The $\chi^2$ for the log likelihood ratio test of the hypothesis that the exogenous variables included in the model have zero influence on the extent of adoption (i.e. $\beta_i = 0$) was rejected at 0.01 probability level. The estimated proportion of land to be allocated to IMVs at the mean value of all exogenous variables was 43 percent. The results suggest that extension services, yield ratio, variety and geographical characteristics significantly influence the allocation of land to IMVs (Table 3). Farmers' physical and capital endowment has no significant influence on the extent of adoption. Intensity of extension service was the major factor positively influencing the adoption of improved maize seeds. For the whole sample, increase in one unit of extension service intensity increased the average proportion of land allocated to IMVs by 94 percent and the probability of adoption by 66 percent for nonadopters. The same unit increase in the intensity of extension service increased the average proportion of land allocated to IMVs by 66

**Table 3.** Results of Tobit Estimates on Proportion of Land Allocated to Improved Maize Seeds

| Variable | Estimated Coefficient | Asymptotic Standard Errors | $\delta EY/\delta X_i$ | $\delta EY^*/\delta X_i$ | $\delta F(z)/\delta X_i$ |
|---|---|---|---|---|---|
| Constant | −0.01294 | 0.38295 | −0.0114 | −0.0081 | −0.0080 |
| Household head age in years (AGE) | 0.00208 | 0.00478 | 0.0018 | 0.0013 | 0.0013 |
| Adults in a household (LAB) | −0.00614 | 0.02576 | −0.0054 | −0.0038 | −0.0038 |
| Household head education (EDU) | 0.03523 | 0.02273 | 0.0312 | 0.0220 | 0.0218 |
| Wealth index (WID) | −0.01731 | 0.01324 | 0.0153 | 0.0108 | 0.0107 |
| Extension index (EXI) | 1.06410 | 0.27623** | 0.9409 | 0.6653 | 0.6571 |
| Yield Ratio (YRATIO) | 0.00334 | 0.00166** | 0.0030 | 0.0021 | 0.0021 |
| Varieties in Group 1 (VA1) | 0.67947 | 0.16429** | 0.6005 | 0.4246 | 0.4193 |
| Varieties in Group 2 (VA2) | 0.76908 | 0.13203** | 0.6800 | 0.4809 | 0.4749 |
| Agroecological Zone 1 (AEZ1) | −0.83788 | 0.22988** | −0.7409 | −0.5239 | −0.5174 |
| Agroecological Zone 2 (AEZ2) | 0.02395 | 0.17971 | 0.0110 | 0.0077 | 0.0077 |
| Low lands (LOW) | 0.39752 | 0.18128** | 0.3515 | 0.2485 | 0.2455 |
| Sample size | | | | 293 | |
| Variance of the estimates | | | | 0.2096 | |
| Probability of adoption (PLAND > 0) at mean of independent variables | | | | 0.7946 | |
| Observed frequency of adoption (PLAND > 0), F(z) | | | | 0.7031 | |
| Expected proportion of adoption at mean value of all independent variables | | | | 0.4295 | |
| z-score | | | | 0.5300 | |
| Standard normal density function, f(z) | | | | 0.3467 | |
| Likelihood ratio test statistic | | | | 87.538** | |

Single or double asterisks denote statistical significance at 5% and 1% probability level $dEY/dX_i$ = Marginal effect of explanatory variable on the expected value of the depended variable, $dEY^*/dX_i$ = Marginal effect of explanatory variable on extent of adoption among adopters $dF(z)/dX_i$ = Probability change of adoption given a unit change of explanatory variable among non adopters

percent for adopters. Although the extension intensity indicator used is a crude representation of availability of extension service in the area, it is a good indicator of farmers' knowledge of agricultural information. Since the major source of agricultural information in the study is the extension personnel, the results emphasize the importance of extension services in the adoption of improved maize seeds.

Farmers growing long (VA1) and intermediate (VA2) maturing varieties were more likely to allocate more land to improved maize seeds than farmers growing short maturing varieties (VA3). The probability of growing short and intermediate varieties by non-adopters was higher by 41 percent and 47 percent, respectively, than non-adopters growing short maturing varieties. On average, the proportion of land allocated to improved maize seeds for long and intermediate varieties was higher by 60 and 68 percent respectively as compared to short maturing varieties. For adopters, the average proportion was higher by 42 and 48 percent for farmers growing long and intermediate maturing varieties, respectively. In low rainfall areas, AEZ1, farmers were less likely to adopt improved seeds than farmers in the high rainfall areas, AEZ3. For the whole sample, the average proportion of area allocated to IMVs in AEZ1 was lower by 74 percent compared to areas in AEZ3. No significant difference was observed on land allocated between intermediate AEZ2 and AEZ3. Improved maize seeds do better than local varieties in high rainfall areas.

Farmers in the lowlands were more likely to adopt improved maize seeds than farmers in the intermediate zone. The average proportion of land allocated to improved maize seeds in the lowland was higher by 35 percent compared with the intermediate zone. The probability of adopting improved maize seeds for farmers in the lowlands was higher by 25 percent. The lowlands generally receive lower rainfall than the intermediate altitude areas. We would expect higher adoption in the intermediate altitude. These results can be related to the effect of research and extension activities. Most research and extension activities are conducted in the lowlands to reduce the risk of production associated with low rainfall. Ilonga Research Station (Eastern Zone), a lead center for maize research in Tanzania, is in the lowlands and so are the other outreach research stations, i.e., Hombolo in the Central Zone and Mubondo and Tumbi in the Western Zone. The presence of these research stations may affect adoption positively as most of the on-farm evaluation and demonstration trials are conducted within the vicinity of the research stations.

### *Use Of Inorganic Fertilizer For Maize Production*

The probit model results explaining the incidence of inorganic fertilizer use for maize production are presented in Table 4. The $\chi^2$ for the log likelihood ratio test for the hypothesis that the exogenous variables included in the model have zero influence was rejected at 0.01 probability level. The results suggest that extension intensity, yield ratio and variety characteristics significantly and positively influenced the use of inorganic fertilizer. Increase in intensity of extension services and yield ratio by one unit increased the probability of using fertilizer by 96 and 0.26 percent respectively. Farmers growing varieties in Group 1 and 2 were more likely to use fertilizer than farmers growing varieties in Group 3, the probabilities being higher by 28 and 27 percent respectively. Farmers in AEZ1 and AEZ2 were less likely to use fertilizer than farmers in AEZ3, the probability being lower by 63 and 28 percent respectively. The wealth index had a negative impact on adoption of fertilizer. Increasing the wealth index by one unit decreased the probability of using fertilizer by 0.74 percent.

As shown in Table 1, most farmers prefer Group 3 varieties that are low yielding but can escape moisture stress. Also, Table 2 shows the mean yields of IMVs with fertilizer were relatively higher in all agroecological zones but had higher yield variability compared to yield without the use of fertilizer. Coupled with the fact that only 56 percent of the sample farmers used fertilizer for maize production, the sample farmers can be assumed to be risk averse. However, as mentioned before, relatively poor farmers use input intensification to manage risk whereas relatively rich farmers use extensive production and diversification for the same effect. The negative sign on the wealth index is an indication that risk management factors dominate the purchasing power of farmers in adopting input-intensive technologies. This means that relatively poor farmers are more likely to use inorganic fertilizer to increase total production from the farm as they have no other alternatives. Thus, poor farmers are vulnerable to yield risk. The risk is cushioned by planting Group 3 varieties that can escape moisture stress and minimize the negative effect of fertilizer use.

The human capital variables, i.e. age and labor, marginally increased the probability of using fertilizer by 0.04 and 0.4 percent, respectively. Also, farmers in the lowlands were 23 percent more likely to use fertilizer than farmers in the intermediate zone. These results enforce the Tobit model results in Table 3. Successful use of inorganic fertilizer requires availability of enough moisture, otherwise production can be suppressed. As stated before, it was expected that incidence of fertilizer use will be higher in the intermediate altitude where rainfall is relatively higher than in the lowlands. However, the high concentration of research and extension in the lowlands may have influenced the results.

Land allocated to improved maize seeds has a negative but non-significant influence on fertilizer use. The negative sign on PLAND* variable in the FERT equation is an indication that farmers with more land allocated to improved maize seeds production do not use inorganic fertilizer. This indicates that the adoption of inorganic fertilizer is not significantly influenced by the adoption of improved maize seeds. The results reject the simultaneous

**Table 4.** Probit Model Estimates on the Incidence of Fertilizer Use (FERT)

| Variable | Estimated Coefficient | Asymptotic Standard Error | $\delta EY/\delta X_i$ |
|---|---|---|---|
| Constant | −0.84438 | 0.59648 | −0.3242 |
| Land allocated to IMVs (PLAND*) | −0.00073 | 0.25370 | 0.0003 |
| Age of household head in years (AGE) | 0.00105 | 0.00698 | 0.0004 |
| Adults in a household: Age > 18 years (LAB) | 0.00949 | 0.03946 | 0.0036 |
| Education of household head in years (EDU) | 0.02111 | 0.03314 | 0.0081 |
| Wealth index (WID) | −0.01937 | 0.02667 | −0.0074 |
| Extension index (EXI) | 2.50820 | 0.45485** | 0.9631 |
| Yield Ratio (YRATIO) | 0.00677 | 0.00279** | 0.0026 |
| Varieties in Group 1 (VA1) | 0.71940 | 0.27554** | 0.2762 |
| Varieties in Group 2 (VA2) | 0.70330 | 0.21167** | 0.2701 |
| Agroecological Zone 1 (AEZ1) | −1.63990 | 0.33217** | −0.6297 |
| Agroecological Zone 2 (AEZ2) | −0.74004 | 0.26160** | −0.2842 |
| Low lands (LOW) | 0.59242 | 0.27373** | 0.2275 |
| Sample size | | 293 | |
| Percent of right prediction | | 78.50 | |
| Maddala $R^2$ | | 40.03% | |
| Observed frequency of adoption (FERT > 0), F(z) | | 0.5291 | |
| z-score | | 0.05 | |
| Standard normal density function, f(z) | | 0.384 | |
| Likelihood ratio test statistics | | 69.282** | |

Single or double asterisks denote statistical significance at 5% and 1% probability level
IMVs = Improved maize varieties
$dF(z)/dX_i$ = Probability change of adoption given a unit change of explanatory variable among non adopters

adoption of improved maize seeds and inorganic fertilizer. Nkonya *et al.* also observed a step-wise adoption of improved seeds and fertilizer in Northern Tanzania. In their study, adoption of improved seeds by itself appeared to be a likely first step in the adoption process, just as was found in this study.

## Conclusion And Policy Implications

This study showed that extension services, yield difference between improved and local varieties, and geographical characteristics significantly influenced the adoption process of improved maize seeds and inorganic fertilizers. The study emphasized the importance of extension services and farmer participation in the research process. Extension service was shown to be an important source of knowledge for farmers that significantly influenced the adoption of improved maize seeds and fertilizer. Currently, there is no short cut for substantial and dramatic increases in production of maize without improved seeds and use of inorganic fertilizer. Use of organic fertilizer such as manure is limited by many factors. Due to increased demand for land for crop production, coupled with population growth, livestock are pushed away from the villages and arable land to village peripheries and marginal areas. Use of manure for production purposes is highly limited by transportation from livestock kraals to maize fields. Since maize is a staple food and occupies a strategic position in the Tanzanian economy, the need to strengthen extension services in the area cannot be over-emphasized.

Variety characteristics embed risk and risk management factors that suit the socioeconomic circumstances and environmental requirements of farmers. The participation of farmers in the research process encourages the flow of information between researchers and farmers. In the process, technologies based on farmers' needs can be developed and can contribute to achieving the target of food self-sufficiency in Tanzania. As mentioned before, the limitation of this study, as with most cross-sectional analyses limited to a single-visit survey, preclude inclusion of some economic factors likely to influence the adoption process. Factors such as price of input and output, taste and preference of individual households, input distribution and availability may enhance or limit the adoption and diffusion process of the technologies. To develop a realistic maize research and extension program in the area, these factors have to be taken into consideration. Future surveys should collect all economic information that influences the choice of technologies. Such information is important in the adoption studies and in developing comprehensive research and extension programs.

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