RESEARCH REPORT 94

FERTILIZER USE ON SMALLHOLDER FARMS IN EASTERN PROVINCE, ZAMBIA

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FOREWORD

In Sub-Saharan Africa, which so far has benefited little from the green revolution, the adoption of high-yielding maize has great potential for closing the gap between food demand and supply. To bring about this transformation, fertilizer is essential for realizing the yield potential of hybrid maize while sustaining the fertility of Africa's fragile land. This study of Eastern Province, Zambia, shows that use of fertilizer on traditional varieties can also be a catalyst for agricultural growth.

This work is part of an extensive body of research on adoption of new agricultural technology carried out by IFPRI in Asia and Africa. The study was undertaken in collaboration with several Zambian institutions, including the Rural Development Studies Bureau (University of Zambia), the National Food and Nutrition Commission, and the Eastern Province Agricultural Development Project (both of the government of the Republic of Zambia). It was funded by the Swiss Development Cooperation.

The relationship between technological change and government policy has always been an important part of IFPRI's research program.IFPRI's ongoing research on fertilizer use is part of an effort to devise workable policies for translating new technology into rapid agricultural growth and sustainable development that benefit all segments of society, but particularly the poor. It also relates to other IFPRI research on input market reforms, which examines ways to improve access of the poor to inputs such as fertilizer through efficient pricing and distribution policies.

Per Pinstrup-Andersen
Director General

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SUMMARY

This study, conducted in Eastern Province, Zambia, looks at farmer's practices regarding use of fertilizer and analyzes the role of fertilizers in the transition from subsistence farming to a more commercialized agriculture. The findings here are also relevant for similar agroecological zones in central and southern Africa.

The study is based on data collected from 330 households in Eastern Province by the International Food Policy Research Institute (IFPRI) in collaboration with Zambian research institutions during 1985/86 and on data provided by the Department of Agriculture and the Adaptive Research Planning Team, which conducted field trials for the Eastern Province Agricultural Development Project, funded by the World Bank, during 1983-87.

Eastern Province has recorded impressive gains in agriculture since the late 1970s and has contributed increasingly to national food stocks, particularly of maize. Most of this growth has come from the plateau region, which covers nearly half of the province and has 80 percent of the population. The other region of the province, the Luangwa Valley, is heavily infested with tsetse flies and is lacking in infrastructure and support services. Since fertilizer use was negligible in the valley region—only 6 percent of the sample households used fertilizers—the analysis in this report is confined to the plateau sample. About 96 percent of the farms in the province are less than 10 hectares, although it is a land-surplus area. Maize is the dominant crop, accounting for more than 80 percent of the cultivated area in the plateau and about 60 percent in the valley. Groundnuts are the other major crop in the plateau. Fertilizer use in Eastern Province began in the late 1960s, mainly on hybrid maize. Belying the national trend, fertilizer use continued to grow impressively through the mid-1980s when the province accounted for nearly a quarter of national consumption of fertilizer.

Experiments conducted at the Msekera Agricultural Research Station and on farmers' fields in the province during 1983-87 indicated that physical responses to fertilizer application in the plateau region were high, ranging from 16 to 22 kilograms of grain per kilogram of plant nutrients for hybrid maize and from 9 to 15 kilograms for local maize at recommended levels. Cotton and beans also responded well to fertilizer in tests, but farmers use fertilizer almost exclusively on maize. Interactions between fertilizer and different agronomic practices such as time of planting, weeding, crop rotation, and time of fertilizer application were established, findings that have been explicitly incorporated in extension messages in the province.

The high physical response to fertilizer in the plateau was supported by a favorable price environment during the 1980s. Fertilizer prices rose sharply after 1980, but maize prices kept pace, and relative fertilizer prices remained favorable until 1989/90, when real prices increased by 81 percent.

Data collected in the IFPRI survey show that the use of fertilizer has been widely adopted by smallholders in the plateau region. About 67 percent of the sample households used fertilizers, and more than 55 percent of the cropped area was

fertilized at an average rate of 96 kilograms of total plant nutrients ($N + P_2O_5 + K_2O$). The average rate of application per hectare of cultivated land was about 53 kilograms—more than three times the national average. These numbers conceal substantial variation in the plateau, however, where use varied from 20 to 100 percent among locations.

Hybrid maize accounted for 54 percent of the total fertilizer used; the rest was allocated to local maize. About 48 percent of fertilizer was allocated to mixed stands of local and hybrid maize varieties. However, fertilizer use recommendations are based on pure stands, because little research has been done on responses of mixed crops.

During the survey year, 49 percent of the fertilizer users applied fertilizer to local maize only. This goes against the traditional wisdom regarding diffusion, which holds that in a cross-section of households there will be some new fertilizer users who fertilize only hybrid maize and others with more experience with fertilizers who will use it on both hybrid and local varieties. A probit model designed to identify the distinguishing characteristics of farmers who only fertilize local maize shows that smaller farmers, households headed by females, older farmers, and farmers with fewer dependents are more likely to apply it only to local maize. This implies that even those farmers who could not (because of limited labor or capital) or did not (by preference) grow hybrid maize found it advantageous to use fertilizer. Apparently, knowledge regarding fertilizers is so widespread that farmers are aware that it pays to fertilize local maize.

Rates of fertilizer application varied across different agro-ecological zones within the plateau. In general, fertilizer users tended to use all three major nutrients, although in some locations, inadequate supplies of mixed fertilizer forced farmers to use only a top dressing (nitrogen) fertilizer such as urea. Substitutions led to divergences from recommended levels and imbalances in the use of nitrogen and phosphorous in some cases.

Fertilizer use parameters—adoption (use), crop area fertilized, and rates of application—did not vary significantly across farm size categories. Only on commercialized farms of more than 5 hectares were the indicators sharply higher. However, the pattern of fertilizer allocation between crops did change as farm area increased, shifting from local maize to hybrid maize.

Constraints in the fertilizer distribution system were inferred from analysis of the fertilizer purchase patterns of sample households. Less than 3 percent of the total quantity of mixed fertilizers used was of the recommended X mixture (20-10-5 NPK). In some locations where even the D mixture (10-20-10) was not available, farmers were forced to use only nitrogenous fertilizers. Lack of the recommended fertilizer mixture raised farmers' fertilizer costs by about 16 percent and created inefficiency in timing of application. Availability of fertilizers at the right time also depended on physical access; farmers had to travel from 0.7 to 9 kilometers to obtain fertilizers, depending on location.

Only 15 percent of the farmers used institutional credit, although more than 66 percent used fertilizers. Among fertilizer users, more than 75 percent did not use credit during the 1985/86 season.

Farmers' fertilizer use behavior was analyzed through an econometric model that considers two simultaneous decisions—whether to use fertilizers and how much to apply. The model postulates that these decisions are influenced by a common set of personal variables (age, education, sex, and subsistence pressure), resource endowment variables (family size, cultivated area, oxen use, crop sales, and hybrid use), institutional access variables (cooperatives, extension, markets, and fertilizer supply), and location variables (agroecological).

The results on adoption indicate that younger farmers were more likely to use fertilizers, as were those who had better access to capital either through farm sales or through membership in cooperatives. Fertilizer supply conditions and access to markets affected this decision significantly. The results did not support the view that households headed by women lagged behind in use of fertilizer, but they were reluctant to grow hybrid maize and therefore more likely to use fertilizers on local maize only. The extension advice and education variables were not found to be significant, probably because knowledge about fertilizer use was already widespread.

As farmers gained familiarity with fertilizers and began making more complex decisions on fertilizer levels to be used, the study finds that education and extension advice assumed greater importance.

Membership in a cooperative and access to markets—variables found to be important in the decision to use fertilizers—were not significant in the decision on how much fertilizer to use. The only market-related variable that mattered was the quality of input distribution in the area.

Farmers' fertilizer allocation behavior was also examined to gain insight on the process of transition from subsistence to commercial farming. It was hypothesized that fertilizer use on local maize triggered the transition process in Eastern Province. The resulting surplus was used to expand cultivated area and area under hybrid maize, culminating in larger farms and commercial maize production. Empirical evidence based on an ordered-probit model shows that education, credit, and improved access to infrastructure facilitated this process and inefficiencies in fertilizer distribution dampened it. Older farmers and farm households headed by women found it difficult to make this transition. Availability of land, existence of a labor market, possibility of using oxen for cultivation, and a favorable price and market environment all contributed to the process.

Some important policy conclusions emerge from these findings. First, regions of high physical response, like the Eastern Province plateau, can sustain rapid growth in fertilizer use and agricultural production. It is, therefore, more efficient to target scarce fertilizer and supporting infrastructure to these areas.

Second, Zambia's favorable incentive environment made it profitable to use fertilizers on maize. A recent deterioration in relative fertilizer prices may have an adverse effect, especially because fertilizer use is concentrated on only one crop. In the long run, it will be necessary to diversify the crop base.

Third, public investments in schooling, infrastructure, and credit institutions were important determinants of fertilizer use and commercialization. The research and extension systems have also contributed. And, in Zambia, the state has procured all the maize surpluses that farmers produced. These findings emphasize the critical role of public investments in modernizing African agriculture.

Finally, the study shows that fertilizer use can trigger the process of transition of subsistence agriculture to commercialized farming. Under favorable circumstances, yield-increasing technologies offer viable opportunities even in land-surplus regions. Development strategies for regions with poor endowments, like the Luangwa Valley in Eastern Province, require more research on their agriculture and farming systems.

2

INTRODUCTION

The crucial role of chemical fertilizers in Africa's agricultural future is well recognized (FAO 1981, 1986; Mellor, Delgado, and Blackie 1987; Lele, Christiansen, and Kadiresan 1989). Evolving population-food imbalances underscore the critical role of new and improved agricultural technologies, and fertilizers constitute a key component of this strategy. Actual performance regarding the use and diffusion of chemical fertilizers in different countries of Sub-Saharan Africa has, however, been generally disappointing. Levels of fertilizer use continue to be low. Growth in fertilizer consumption has faltered in Africa, lagging behind that for developing countries as a whole (Desai and Gandhi 1989).

In summarizing the fertilizer-related experiences of selected countries in Africa, Lele, Christiansen, and Kadiresan (1989, 6) identify supply and demand constraints that inhibit growth in fertilizer consumption:[1] "The underutilization of fertilizer makes fertilizer pricing, subsidy, and distribution policy, together with the alleviation of other technological and institutional constraints, one of the most pressing issues in the modernization of African smallholder agriculture."

From another perspective, researchers have emphasized the need to examine the nature of farming systems before deciding on appropriate technological interventions. Large parts of the continent, it is argued, are characterized by land-abundant forest or bush-fallow systems, where yield-increasing technologies like fertilizers have limited relevance (Binswanger and Pingali 1988). This perception helps explain the observed low use of biochemical technologies for food crop production. This system constraint notwithstanding, active public policy with regard to regional targeting, infrastructure, research and extension, prices, marketing, and so forth can, even in such situations, promote these technologies and help achieve rapid production and income growth (Binswanger and Pingali 1988; Lele and Stone 1989).

Micro studies in different agroeconomic settings are, therefore, essential to understanding the variations that characterize the African fertilizer scene. Scores of such studies have helped rationalize and formulate policies in Asia, for example, where fertilizer use has grown dramatically over the last two decades. Similar efforts have been lacking in the African context. In fact, many more studies are needed in view of the large variability in farming systems, economic environment, and infrastructure conditions over the continent.

This research reports the results of one such study conducted in the Eastern Province of Zambia—a country endowed with abundant land resources. It is based on data collected from 330 smallholder households during the 1985/86 agricultural year. Fertilizer consumption in Zambia has remained stagnant over the last 10 years,

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[1]Fertilizer supply includes fertilizer imports, aid, and distribution, and demand includes relative fertilizer prices, crop response to fertilizer application, credit, and other facilitating institutions.

although Eastern Province has recorded significant gains in fertilizer consumption as well as output growth. In addition to analyzing the pattern and determinants of fertilizer use on farms, this study also tries to further understanding of the process of the transition from subsistence to commercial agriculture by analyzing differences in fertilizer allocation behavior among farmers. The major objectives of the study are (1) to describe the use pattern of chemical fertilizers by smallholder farms in Eastern Province; (2) to identify the major determinants of fertilizer adoption and uses, and (3) to examine the role of fertilizers in promoting agricultural transformation of the area.

A brief background of the study area is provided in Chapter 3. Chapter 4 focuses on the physical fertilizer response environment and the profitability of fertilizer use, based on on-farm and experiment station trials conducted by the Adaptive Research Planning Team (ARPT) of the Eastern Province Agricultural Development Project (EPADP) during the period 1983-87.[2] The relative price scenario is also briefly reviewed. This is followed in Chapter 5 by an analytical description of fertilizer use practices of smallholders, including adoption and levels of use. Chapter 6 examines farmers' access to fertilizers and credit. An econometric analysis of determinants of fertilizer use is undertaken in Chapter 7, and fertilizer allocation behavior is studied in Chapter 8. The final chapter highlights the major conclusions and policy implications of the study.

Analytical Framework

In almost all developing countries chemical fertilizers were introduced into the main agricultural systems in the years following the Second World War. Prior to that, the use of chemical fertilizer was confined to some plantation or cash crops. Research on farmers' responses to this innovation and factors affecting those responses has drawn heavily from the adoption-diffusion framework of sociology and anthropology, on the one hand, and from factor demand theory on the other. Such studies range from socio-cultural-economic determinants at the farm household level to more aggregative, often time-series, analyses incorporating the role of prices, environmental and other shifter variables, and policy factors.[3] From these studies inferences have been drawn regarding appropriate interventions to augment fertilizer use, such as research, extension, credit, irrigation, and price policy.

A complementary, evolutionary framework focuses on the *processes* governing growth in fertilizer use. As is evident from the following quotation, several of these processes are still nascent in the developing-country context and hence act as constraints. This perspective emphasizes the institutional dimensions.

> Forces behind growth in fertilizer use may be viewed as development of and interactions among four sets of processes: (1) those that influence the economic potential of fertilizer use through development of resources such

[2]EPADP was established with World Bank funding in 1982. Raising agricultural production through rapid diffusion of improved technology was the main objective of the project. Major emphasis was placed on reorganization of the extension system along training and visit (T&V) system lines.

[3]See Feder, Just, and Zilberman 1985 for a comprehensive review.

as irrigation and new technology that shift fertilizer response functions upwards; (2) those that convert the potential into farmers' effective demand for fertilizers by providing them with knowledge on fertilizer use, credit, and assured markets for output; (3) those that determine the growth of aggregate fertilizer supply through imports and domestic production; and (4) those that help develop geographically dispersed fertilizer distribution systems and determine how they operate. (Desai and Gandhi 1990).

This study, based on cross-sectional household data at a subnational level, essentially uses the adoption-diffusion framework. Differences in fertilizer use between households are examined in relation to socioeconomic, cultural, and specific farm characteristics. Prices and other dynamic variables cannot be included in such models. A descriptive analysis of some of these processes is nevertheless provided, and this insight is used to understand the observed differences. Also, locational differences in market access and fertilizer supply conditions observed in cross-sectional data do allow incorporation of some of these variables into the analysis.

In a broader context, a cross-section of farming households in a growing, dynamic setting does, in a sense, capture individuals in different stages of transition as they try to move from traditional to modern agriculture. Some persist with traditional modes, others are experimenting with new ideas, while some have already achieved high levels of modernization. Using a suitable criterion for classifying individuals in different categories of transition, one can decipher forces or factors that govern this process. In this study, an attempt is made at an exploratory analysis along these lines, using fertilizer allocation behavior as a criterion.

Literature on fertilizer diffusion in developing countries suggests that fertilizer use starts with high response crops and then spreads to other crops in a hierarchical fashion as agriculture becomes more progressive. This process is used to depict the transition from subsistence farming with no fertilizer use to greater commercialization and modernization of the smallholder farming sector.

A progressive transition of this kind has, in fact, been articulated by Zambian development workers in the concept of a *lima* ladder. A *lima* is a unit of land (0.25 hectare). This step-by-step approach begins with a subsistence farmer and, as a first step, introduces a small area (a *lima*) of a cash crop such as soybeans or sunflowers (see Appendix 1, Figure 4). Sales from this activity generate cash to purchase fertilizers to be used on local maize the next year. The increase in maize further improves the farmer's cash position, and so in the third year local maize area is reduced and hybrid maize is added. Up to this stage, area expansion is restricted because of labor constraints. In the fourth year, the farmer has enough cash to hire oxen and expand his hybrid maize area. Fertilizer plays a key role in this scheme. Using the observed fertilizer use pattern on farms as an indicator of this transitional pathway, the analysis seeks to identify factors that influence this process.

Data and Limitations

Eastern Province is divided into six administrative districts, namely, Chadiza, Chama, Chipata, Katete, Lundazi, and Petauke. The provincial Department of Agriculture has demarcated 10 agricultural districts. This study is based on a representative sample of 330 smallholder households spread over 9 agricultural districts in the province. The survey was conducted as part of a collaborative study entitled "Growth and Equity in Zambian Agriculture," funded by the Swiss Development Cooperation. The International Food Policy Research Institute (IFPRI), the Rural Development Studies Bureau, University of Zambia (RDSB), the National Food and Nutrition Council (NFNC), and Eastern Province Agricultural Development Project (EPADP) were the collaborators. Appendix 2, Table 24, shows the distribution of sample households across districts. From each district, a cluster of villages (called a branch) was selected randomly. In Lundazi District, two clusters were selected. From each branch about 33 households were selected for detailed data collection. Household activities were monitored and data collected by resident enumerators from November 1985 to December 1986. The range of information gathered included area measurements, monthly income, expenditures, labor use, crop cultivation practices, inventory of assets, access to institutions and services, technical assistance, household decisionmaking, nutrition and consumption, and off-farm activities. Data were also collected from reports of the provincial Department of Agriculture on general agricultural characteristics of the province, and from the annual reports and other bulletins of the Adaptive Research Planning Team of the EPADP on fertilizer responses and recommendations.

Since 1985/86, the survey year, dramatic changes have taken place in the macroeconomic environment in Zambia. To the extent possible, the relevant changes have been incorporated in the analysis. While no comment can be made on how farmers have responded to these changes, the basic conclusions are nevertheless enduring and remain relevant.

3

BACKGROUND OF THE STUDY AREA

Zambia is endowed with abundant land resources. Of a total arable area of about 9 million hectares, only 1.4 million hectares are currently cultivated. Population densities in the countryside are low and projections suggest that despite high population growth rates, Zambia will remain a low-density region until about the second half of the twenty-first century (Binswanger and Pingali 1988). In agricultural performance, however, the country follows the trend of declining per capita food availability that is prevalent in most other countries in Sub-Saharan Africa (World Bank 1981).

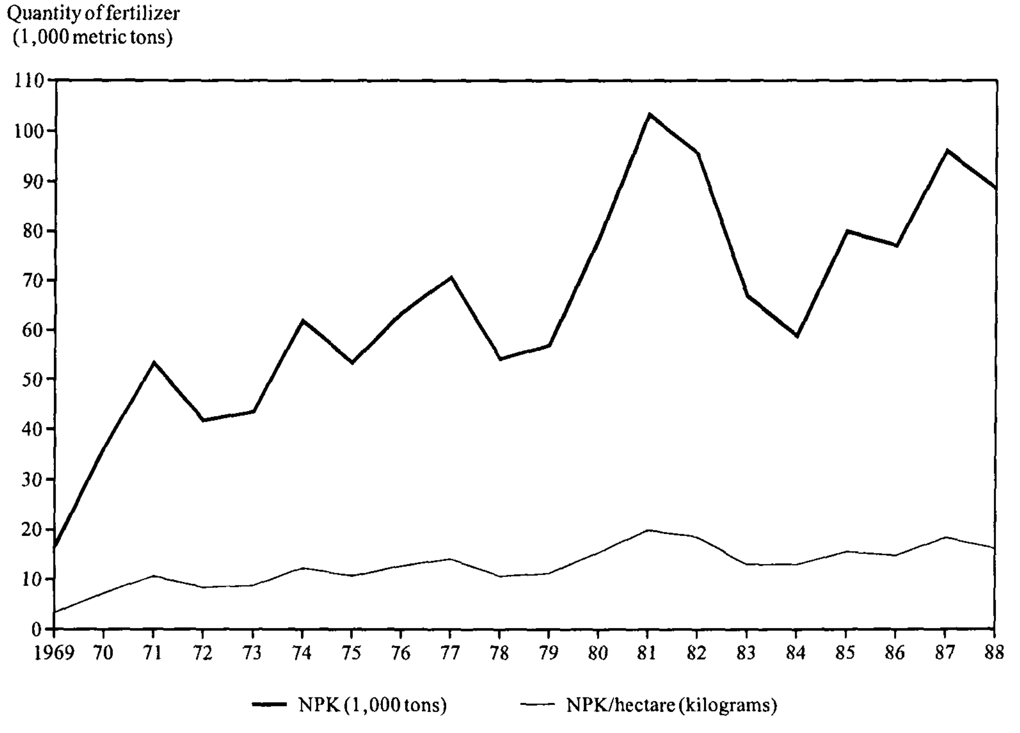
Promoting fertilizer use has been an important element of Zambia's agricultural strategy since the 1950s. Prior to that the focus was on good crop husbandry and land conservation measures. Total fertilizer (nutrient) consumption grew from less than 20,000 metric tons in the late 1960s to more than 103,000 tons in 1981, but it has faltered since then, fluctuating between 60,000 and 95,000 tons in recent years (Figure 1).[4] Fertilizer use intensities are low, declining from about 20 kilograms per hectare of arable land in 1981 to 15-16 kilograms in recent years. The use is highly concentrated—nearly 90 percent of Zambia's total fertilizer use is on maize. The smallholder sector accounts for about 80 percent of the nation's aggregate consumption. More than 80 percent of the current fertilizer supplies come from imports, including concessional aid (Muleya 1990). It has been argued that the uncertainties of donor assistance have contributed to the recent deceleration and instability in fertilizer consumption in the country.

These trends are partly reflected in the data for Eastern Province. The population density, at 9.6 persons per square kilometer in 1985, is marginally higher than the national average (7.5 persons per square kilometer). The annual cropped area represents only 19 percent of the total area and 35 percent of the arable land base of the province, indicating easy access to land. The population growth rate is lower and the proportion of rural population is much higher than the national average (NCDP 1989). The province has recorded significant gains in fertilizer consumption since 1981 (Table 1). By the mid-1980s it accounted for about 20 percent of the total fertilizer consumption in the country in some years, although its share of the total area is less than 10 percent. Even when national consumption of fertilizer faltered during the early 1980s (Figure 1), use in Eastern Province continued to grow impressively. The pace has slowed since.

In Eastern Province, agriculture is dominated by smallholders. About 96 percent of the farms are less than 10 hectares in size; 72 percent are categorized as traditional and 24 percent as small-scale commercial farms (Katongo 1988). Data from the Eastern Province Department of Agriculture suggest that the cultivated area grew by almost 10 percent per year between 1978/79 and 1985/86; most of this increment (93

[4]All tons referred to in this report are metric tons.

Figure 1—Fertilizer consumption in Zambia, 1969-88



Source: Food and Agriculture Organization of the United Nations, *FAO Fertilizer Yearbook* (Rome: FAO, various years).

Table 1—Fertilizer sales in Eastern Province and share of total sales, 1981-89

Year	Sales in Eastern Province	Share in National Sales
	(1,000 metric tons)	(percent)
1981	28	13
1982	34	16
1983	40	25
1984	18	13
1985	55	26
1986	39	20
1987	51	21
1988	54	18
1989	60	20

Source: NAMBOARD (National Agricultural Marketing Board), *Annual report and accounts* (Lusaka, Zambia: NAMBOARD, various years).

Note: Sales include total fertilizer material.

percent) is accounted for by maize (Eastern Province, Department of Agriculture various years). This growth in cultivated area is the result of greater use of oxen.

Growth in marketed maize production in the province has been remarkable—the quantities nearly trebled between the late 1970s and the late 1980s (Appendix 2, Table 25): the share of Eastern Province in national supplies rose from less than 1 percent in 1970 to more than 27 percent in 1983 (Mumeka 1991). The growth pattern in Eastern Province is particularly noteworthy because it has emerged largely from the smallholder sector. Groundnuts, the traditional marketed crop of the province (the commonly grown *Chalimbana* variety is well known as an export crop), stagnated during most of this period, though it showed signs of recovery in the late 1980s. As indicated earlier, fertilizer consumption rose steadily until the mid-1980s. Adoption of hybrid maize and animal traction made significant headway in the plateau region (Jha, Hojjati, and Vosti 1991). By all indicators, Eastern Province has been one of the more dynamic regions of the country in agricultural performance.

The province has two distinct agroecological regions—the Eastern Plateau and the Luangwa Valley. A semipermanent bush-fallow system of cultivation prevails throughout the province, although some areas in the plateau region have begun to experience local land scarcity, and fallow periods are being reduced (ARPT various years). The Adaptive Research Planning Team has identified three major agro-ecological zones in each of these two regions (Figure 2).[5] Table 2 shows the major characteristics of these zones. The annual rainfall ranges from 850 millimeters to 1,050 millimeters in the higher-altitude plateau, concentrated between the months of November and April. Agricultural activities are confined to this period. Sowing starts with the onset of rains and harvesting is completed by the end of May. The soils vary from sandy to clay-loam in texture. Over 80 percent of the human and all of the cattle population is concentrated in this region, and oxen cultivation is becoming quite widespread.[6] Consequently, farms are larger in the plateau region. Maize is the dominant crop, accounting for more than 80 percent of the cultivated area. Both traditional and hybrid varieties of maize are grown; the latter is cultivated exclusively as a market crop.

The valley is thinly populated, receives lower rainfall, has higher temperatures, and is heavily tsetse infested. Maize and groundnuts are important in this zone too, but crops like sorghum, rice, millet, and cotton also occupy significant areas. Groundnuts and cotton are the only cash crops in this zone. Hybrid maize is practically nonexistent. As will be shown in Chapter 5, fertilizer use is negligible. Thus, all three major technological options—hybrid maize, fertilizer, and animal traction—are absent from the valley. Farms are smaller in this zone and hoe cultivation prevails.

The Msekera Agricultural Research Station near Chipata, the provincial headquarters, is the main research facility in the province. There is a small substation in the valley (at Masumba), which is slated for upgrading. The Msekera Station is the lead center for groundnut and grain legume research in Zambia. For maize, the lead research center is at Mount Makulu in Lusaka. It directs the maize trials at Msekera.

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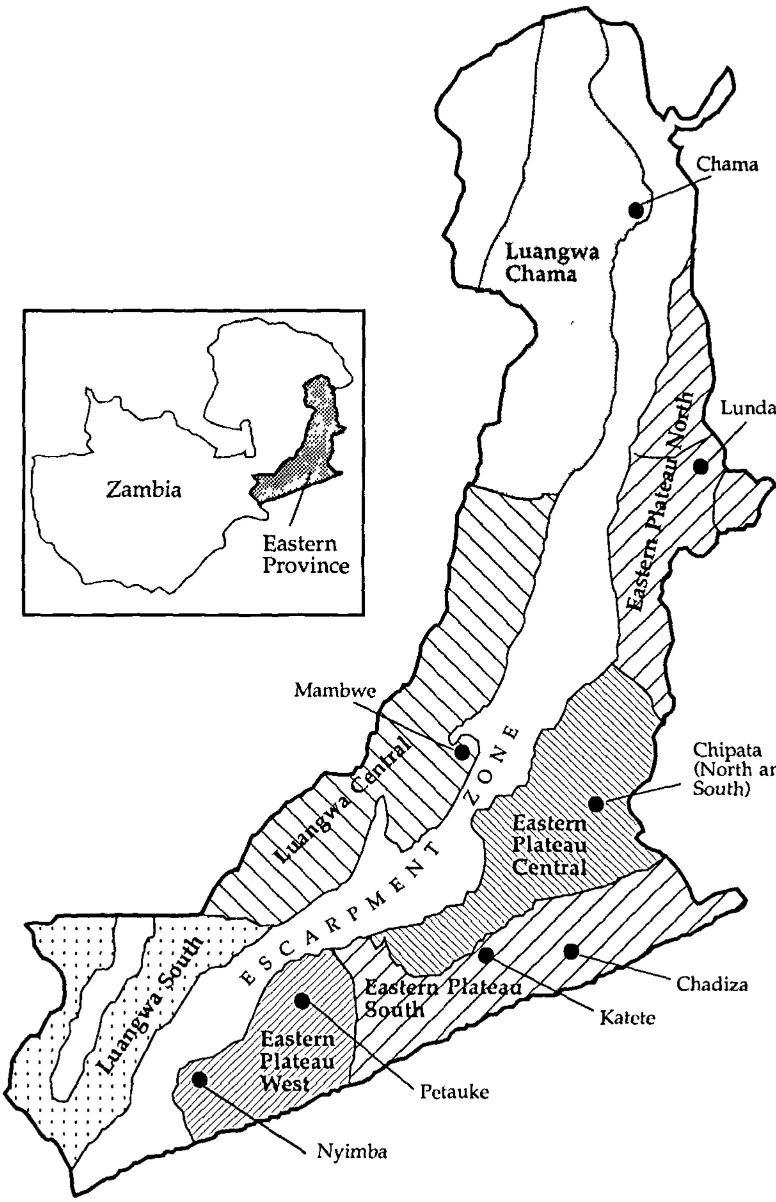
[5]Within each plateau zone, at least two subsystems—hoe and oxen—are also identified.

[6]Note that the incidence of east coast fever makes cattle rearing risky in this zone also. Parts of Katete in the southern zone of Eastern Plateau and the entire western zone of the plateau are identified as vulnerable to tsetse (EPADP 1987).

Figure 2—Agroecological zones and agricultural districts, Eastern Province, Zambia



Source: ARPT (Adaptive Research Planning Team), Eastern Province Agricultural Development Project, "Annual Report, 1985-86" (Chipata, Zambia, 1986, mimeographed).

Note. The households sampled for this study were selected from the agricultural districts shown on the map.

Table 2— Characteristics of agroecological zones in Eastern Province

Item	Eastern Plateau			Luangwa Valley		
	Western	North/South	Central	Chama	Central	South
Altitude (meters)	900-1,500	900-1,500	900-1,500	400-600	400-600	400-600
Mean annual rainfall (millimeters)	900-950	850-1,000[a]	850-1,050	800-900[a]	750-850[a]	700-800
Mean growing season (days)	125	135	140	145	140	125
Predominant soil	Clay-loam	Sandy	Clay-loam	Sedimentary	Variable	Variable
Population density 1980[b] (persons/kilometer)	9.3	11.7	17.1	...	2.0	...
Farm families (1987 estimate) (percent of total)	17	41	24	7	6	4
Cultivated area/farm[c] (hectares)	3.39	2.99	3.20	...	1.39[d]	...
Average family size[c] (number)	6.67	5.77	5.49	...	5.93[d]	...
Cattle population/family[c] (number)	1.7	3.0	1.4	...	...	...
Share of crop area sown[c] (percent)						
Maize[e]	85.4	84.7	82.2	...	58.3[d]	...
Sorghum	...	...	...	...	15.6	...
Millet	...	5.0	...	...	5.6	...
Rice	...	...	...		2.4	
Groundnuts	9.9	4.7	13.4	...	11.1	...
Soybeans	...	1.1	0.2	...	0.4	...
Sunflower	1.6	3.7	1.9	...	...	...
Cotton	1.0	...	0.4	...	2.8	...
Percent of farmers adopting[c]						
Hybrid maize	31.1	42.7	34.4	...	3.2	...
Animal traction	67.2	73.4	27.9	...	...	...

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

Notes: The Adaptive Research Planning Team identified hoe and oxen-based systems in each of the plateau zones. These have been aggregated because data are not available at this level. The ellipses indicate a nil or negligible amount.

[a]Short drought periods occur.
[b]Obtained by district approximation.
[c]Based on the survey for this study.
[d]Based on a survey for Chama and Central zones by the Adaptive Research Planning Team.
[e]Pure and mixed cropping prevail in the province.

The ARPT at Msekera has been conducting on-station as well as on-farm trials on different crops since 1982. Since 1992, the provincial agricultural extension system has been gradually reorganized along training and visit (T&V) system lines under the World Bank-assisted Eastern Province Agricultural Development Project (EPADP). The Research and Evaluation Unit and the ARPT have also been supported by the project. The National Agricultural Marketing Board (NAMBOARD) and the Eastern Cooperative Union (ECU) were the agencies responsible for input and credit supplies and output purchases in the province.[7]

Evidence on Fertilizer Use in Eastern Province

The earliest systematic work on smallholder agricultural systems in the province was conducted in Chipata District in 1971/72 (Harvey 1973). This study showed that fertilizer use was largely confined to hybrid maize and tobacco—both cash crops—though a small proportion (5 percent) of farmers used it on local maize. About 18 percent of the farmers grew hybrid maize, which covered nearly 10 percent of the maize area. Hybrid maize was a new crop; no farmer had grown it for more than three years. Before that time, fertilizer use was practically nonexistent in the smallholder sector. The levels of fertilizer application on hybrid maize were close to those recommended by the extension service.

Since the inception of the EPADP, lack of information on small farm systems has been recognized as a serious handicap. Some small-farm surveys have been conducted by the Research and Evaluation Unit of EPADP and ARPT. A survey in Lundazi District, located in the northern zone of the plateau, which is the highest fertilizer-consuming district in the province, showed that all sample farmers used fertilizer on local as well as hybrid maize, often at higher than recommended levels. No other crop was fertilized. In this high-adoption location, 74 percent of the farmers were growing hybrid maize, and animal traction was common (EPADP 1984). A similar survey in Eastern Plateau South revealed significant inefficiencies in fertilizer use practices with regard to timing and method of application (ARPT various years). Severe labor constraint around planting time was identified as an important reason for this.

Another small-farm survey, spread over the entire province, was conducted in 1984/85. It showed wide variability in resource endowments and agricultural practices within the province. Fertilizer use was found to be practically nonexistent in the valley region and varied substantially between plateau districts. The districts of Lundazi and Chipata South were found to be high fertilizer-consuming areas, followed by Katete (EPADP 1986b).

Three major conclusions emerge from these surveys. First, very little fertilizer was used in the province until the early 1970s. Fertilizer use picked up with the emergence of hybrid maize as a cash crop, which shifted the fertilizer response curve and profitability of fertilizer use dramatically. Even during these early years, farmers used the recommended levels. Subsequently, farmers extended fertilizer use to local varieties of maize also. In some areas, fertilizer use on hybrid and local maize has

[7]The marketing board, NAMBOARD, has since been dissolved and its function taken over by the cooperative sector.

become universal. In others, the diffusion phase is still going on. In the province, no other crops are fertilized. Second, agroecological conditions play an important role in diffusion of fertilizer use. Fertilizer use in the valley is negligible, and even within the plateau there is considerable variation. Finally, although fertilizer use has become widespread, farmers do not always follow directions for optimal timing or method of application, either because they lack sufficient knowledge or because of labor constraints during the planting and weeding period. Subsequent sections of this report examine these and other related issues in greater detail, based on household data collected during 1985/86.

4

RESPONSE TO FERTILIZER APPLICATION

Traditionally, fertilizer application was recommended only for hybrid maize and tobacco, mainly in the plateau region of Eastern Province. These recommendations were derived from trials conducted at the Mount Makulu and Msekera research stations at Lusaka and Chipata, respectively. Since the inception of the ARPT in 1982, attempts have been made to evaluate crop responses to fertilizer on farmers' fields in the province. This work tries to integrate agronomic and economic considerations. Trials conducted by the ARPT during the period 1982/83-1987/88 are listed in Appendix 2, Table 26, which indicates that by this time the research system was conducting verification trials on farmers' fields for improved practices on crops such as maize, cotton, soybeans, and groundnuts, whereas rice and finger millet trials were still being conducted at the experiment station level. While fertilizer and maize continued to be important in ARPT work, the focus was shifting to other crops and practices.

Fertilizer Use Recommendations

Table 3 shows how fertilizer recommendations evolved from 1982/83 to 1986 based on this work. In the valley region, not enough experimental work had been done to be able to make recommendations, so the same recommendations were given for both the plateau and valley regions. The recommendations in 1982/83 were based on a review of past work (mainly on experimental stations), as well as on current recommendations based on on-station and on-farm trials.

The major focus of fertilizer work in the earlier period was on hybrid maize. Though experimental work indicated a viable response, use of fertilizer on local maize varieties was not pushed strongly by the extension system. Local maize was viewed as a purely subsistence crop, on which the use of costly inputs could not be justified. Groundnuts, the other major crop, did not respond to fertilizers. Other traditional crops like sorghum and rice were not adequately investigated. Cotton showed some response, particularly with plant protection and timely planting, but the major cotton-promoting agency, the Lint Company of Zambia (LINTCO), did not include fertilizer in its package of recommendations, perhaps because it would make the package even more costly.

Early research in the province showed that the major nutrient deficiency in plateau soils was nitrogen. The recommended phosphate and potash levels were essentially for maintenance. Severe sulfur deficiency occurs in parts of the plateau, as well as the valley, but it is adequately corrected by the 10 percent sulfur content in most of the basal fertilizer formulations. Similarly, some locations have the problem of high soil acidity, for which application of lime has been found effective. Research in the valley region was largely neglected.

Table 3—Fertilizer use recommendations for major crops, 1982/83 and 1986

Crop	1982/83	1986
Maize		
Local	200 kilograms per hectare of X mixture at planting or 10 days after emergence	100 kilograms per hectare of X + 100 kilograms per hectare urea 10-15 days after emergence
Hybrid	200 kilograms per hectare of X + 150 kilograms per hectare urea at planting or 10 days after emergence for early-planted hybrids	200 kilograms per hectare of X + 150 kilograms per hectare urea or 200 kilograms per hectare urea 10-15 days after emergence[a]
Groundnuts	Not recommended	Lime at 400 kilograms per hectare on highly acidic soils
Cotton	200 kilograms per hectare of X for early-planted and sprayed crops on light soils, nil otherwise	200-300 kilograms per hectare of X for early-planted and sprayed crops
Sorghum (Valley)	No trial	Not recommended
Soybeans	200 kilograms per hectare of D on phosphate-deficient soils	150 kilograms per hectare of X
Sunflower	Not economical	Not economical
Rice	No trial	200 kilograms per hectare of X on poor soils
Tobacco (burley)	Not available	200 kilograms per hectare of C + 200 kilograms per hectare of ammonium nitrate as top dressing
Carioca beans	Not available	150 kilograms per hectare of X

Sources: 1982/83 recommendations are based on survey of earlier experimental work reported in Adaptive Research and Planning Team, Eastern Province Agricultural Development Project, "Annual Report, 1982/83," Appendix 13 (Chipata, Zambia, 1983). 1986 recommendations are from Eastern Province Department of Agriculture "Guidelines on Fertilizer Use in Eastern Province Farming Systems: A Memo for Agricultural Extension Workers," Chipata, Zambia, October 1986 (mimeo).

Notes: X, D, and C are fertilizer mixtures, where X = 20-10-5, D = 10-20-10, and C = 6-18-12 combinations of N, P_2O_5, K_2O, respectively, and urea = 46-0-0.

[a]Top dressing can be applied up to four weeks after emergence.

Most of these recommendations have been confirmed and refined by the efforts of the ARPT since 1982. Trials on sorghum, soybeans, sunflower, and rice showed poor or uneconomic responses to fertilizer, while carioca beans showed promising results with fertilizer. For the major crop, maize, modifications have been made in the recommendations for local and improved local (MMV600) varieties. In addition, trials have established the nature and magnitude of specific interactions of fertilizer with planting time, weeding, impact of the preceding crop, plant protection, and so forth (ARPT various years). These are now explicitly included in a qualitative manner in the recommendations (Eastern Province, Department of Agriculture 1986b). For example, the following cautionary points are emphasized in training materials for extension workers:

- No fertilizer should be used for cotton if planted late (December).
- Nitrogenous fertilizers should never be used without basal fertilizer.
- Phosphorous must be applied within two weeks of emergence.

- No fertilizer should be applied to local maize if planted after December 20.
- For late-planted hybrids (December), reduce the fertilizer level by half.
- For hybrid maize preceded by beans, soybeans, or groundnuts, reduce the quantity of top dressing fertilizer (urea) by half.
- Benefits from fertilizers are dramatically reduced if weeding is not done properly.

Informal and formal surveys of farmers' practices conducted by the ARPT at different locations conclude that these interactions and farmers' inability to follow correct practices (mainly due to labor constraints at planting and weeding time) are the main factors responsible for less-than-expected yields, particularly for hybrid maize, despite high application rates of fertilizer. Surveys conducted in the Eastern Plateau North and South zones, for example, revealed that 50-60 percent of fertilizer users applied it on the surface or in uncovered holes, and 40-50 percent applied it very late. Similarly, the quantity of fertilizer applied per stand was found to vary considerably from the recommended practice (ARPT 1986). Apart from emphasizing these technical efficiency parameters in the fertilizer recommendations, the ARPT has been trying to address labor constraints by testing varieties and hybrids suitable for late planting and alternative weed management techniques.

Two comments need to be made about the on-farm trials on which fertilizer recommendations are based. First, the main thrust of ARPT work in this area has been on variety and fertilizer response evaluation at different sites within the province. Scrutiny of data for 1982/83-1985/86 indicates that, while some meaningful results have been obtained on variety, fertilizer response trials did not generate statistically valid results in either of the two years (1982/83 and 1983/84) for which details are provided in the annual reports (ARPT various years). Whereas the ARPT has used data on agroclimatic and farming systems characteristics to delineate agroclimatic zones within the province, it has not been able to establish zone-specific responses. This has constrained the capacity of the research system to develop location-specific recommendations. Therefore, the same recommendations are made for the entire province, with modifications suggested to suit individual farm situations.

Second, stability of responses over seasons and the resulting implications for risks have not received analytical attention. In general, the perception is that yields in the plateau region have been fairly stable over years. Table 4 indicates the variations in weather and yields of hybrid and local maize in on-farm trials in the province over a five-year period. The yield levels are remarkably stable over a wide range of weather conditions, represented in the table by the length of the rainy season and the number of drought spells during the growth period.

In order to investigate whether response to fertilizer application also shows similar stability, data from a maize management trial, conducted over three years (1983/84-1985/86) at Msekera Research Station, were examined (Table 5) (ARPT various years). Comparable data were not generated in other trials. These years cover the extremes of weather conditions experienced at this location. The effects of fertilizer on both local and hybrid maize were statistically significant in all three years. Average responses per kilogram of plant nutrient were found to fluctuate by 30-40 percent between years (Table 5). Yet even the lowest figures (9.5 kilograms for local maize and 15.7 kilograms for hybrid maize) are high by tropical field crop standards. This suggests that the response is also favorable in the plateau region from the stability point of view.

Table 4—Weather conditions and maize yield levels at Msekera Research Station, Zambia, 1982/83-1986/87

Year	Start of Rains	End of Rains	Length of Rainy Season	Number of 10-Day Droughts, November 1-March 31	Mean Yield of Maize in On-Farm Trials	
					Hybrid[a]	Local[b]
			(days)		(kilograms/hectare)	
20-year average	November 17	April 10	144	2 3	...	...
1982/83	November 21	April 7	138	4.0	n.a.	2,517
1983/84	November 30	April 1	122	7.0	5,798	n.a.
1984/85	November 5	April 9	155	3.0	5,626	2,294
1985/86	November 5	April 21	167	0.0	5,073	2,317
1986/87	November 1	March 31	150	4.0	n.a.	2,799
Mean					5,499	2,480

Source: EDADP (Eastern Province Agricultural Development Project), "Eastern Province Agricultural Development Project: Project Completion Report" (Chipata, Zambia, November 1987, mimeographed).
Note: n.a. is "not available."
[a]Trials were conducted at 27 sites.
[b]Trials were conducted at 46 sites.

Average Responses and Value-Cost Ratios

The ARPT has worked out average responses and value-cost ratios at recommended levels of fertilizer application to different crops. These are conservative estimates depicting expected responses on farmers' fields in 1983/84 and 1986/87 and are based on results of on-farm trials and researchers' considered judgments (Table 6).

These data indicate that the plateau region enjoyed a favorable physical response environment, particularly for hybrid maize, local maize, cotton, and beans. Among the major crops, hybrid maize had the highest fertilizer use potential. The value-cost ratios indicate that at 1986/87 prices, fertilizer use was profitable on maize, beans, cotton, and tobacco. The other crops in Table 6—groundnuts, soybeans, and sun-

Table 5—Average response of local and hybrid maize to fertilizer application per hectare at Msekera Research Station, 1983/84-1985/86

Year	Average Response per Kilogram of Nutrients	
	Local	Hybrid
	(kilograms)	
1983/84	9.5	18.9
1984/85	15.3	21.8
1985/86	11.7	15.7

Source: Derived from data on Maize Management Trials in ARPT (Adaptive Research Planning Team), Eastern Province Agricultural Development Project, "Annual Report," (Chipata, Zambia, various years, mimeographed).
Notes: The fertilizer effect was statistically significant for both local and hybrid maize in all three years. The fertilizer application was 200 kilograms of 20-10-5 NPK and 200 kilograms of urea.

Table 6—Average response and value-cost ratios for recommended levels of fertilizer application in the plateau region

Crop	Average Response	Value-Cost Ratio 1983/84 Prices[a]	1986/87 Prices[b]
	(kilograms of grain/ kilogram of nutrient)		
Hybrid maize	18 1	4.0	4.3
Local maize			
Traditional	11.1	2.6	2.7
MMV600 variety	13.3	3.2	3.3
Cotton[c]	7.0	3.1	2.5
Soybeans	4.5	2.8	1.6
Groundnuts	. . .	2.8[d]	n.a.
Sunflower	0.8	1.5	1.1
Tobacco[c]	1.4	n.a.	2.3
Carioca beans	6 1	5.1	6.5

Source: ARPT (Adaptive Research Planning Team), Eastern Province Agricultural Development Project, "Annual Report" (Chipata, Zambia, various years, mimeographed).
Notes: X is a 20-10-5 NPK fertilizer mixture. Prices are in kwacha (K).
[a]Maize = K0.31/kilogram, X = K26.75/bag (50 kilograms), urea = K26.75/bag (50 kilograms)
[b]Maize = K0.87/kilogram, X = K80/bag, urea = K63/bag. Later period prices for commodities other than maize are not available.
[c]Responses for cotton and tobacco are in terms of kilograms of lint and dry leaves, respectively.
[d]Response to lime application at the rate of 400 kilograms per hectare in areas where more than 20 percent popping (splitting of immature shells) occurs.

flower—either did not respond or response levels were too low for use to be viable. Rice and sorghum, not shown in the table, also fell in the same category.

Two other studies have reported average responses of maize to fertilizer application, based on farm-level input-output data from the province. A study by Harvey (1973) showed an extremely high response.[8] Using the yield data collected in the survey on which this report is based, Jha (1991) estimated farm-level response at about 6 kilograms of maize per kilogram of plant nutrient for local maize and 19 kilograms for hybrid maize. The latter figure is close to the ARPT estimate but the former is significantly lower. Judging by the enthusiastic adoption of fertilizer use by local maize growers (discussed in Chapter 5), the former appears to be unrealistic.

Fertilizer Prices

Evaluating the impact of price changes on fertilizer consumption and related issues such as fertilizer subsidies is beyond the scope of this study. However, the

[8]Harvey's 1973 study estimated a linear regression relating yield to fertilizer and other factors. The fertilizer variable (defined in kilograms of fertilizer material) was highly significant and indicated an average response of 12.7 kilograms of maize per kilogram of fertilizer. Assuming 40 percent nutrient content in fertilizer, this implies an average response of about 32 kilograms. Considering that the observation included local as well as hybrid maize plots, this number is very high.

price situation is briefly reviewed in order to provide an indication of the economic viability of fertilizer use.

Fertilizer prices have been rising since 1980 (see Appendix 2, Table 27). Big jumps occurred in 1983/84, 1986/87, 1988/89, and 1989/90. The last one was most dramatic—the price of urea increased by 441 percent and D compound (10-20-10) by 302 percent, compared with 1988/89.[9] The average price per kilogram of plant nutrient rose by 315 percent; the maize price also increased about 100 percent in 1986/87 and 127 percent in 1989/90, compared with the preceding years.

Figure 3 shows the movements of the nutrient-maize price ratio in Zambia since 1980/81.[10] Despite large fertilizer price increases, the nutrient-output (maize) price ratio did not rise very high until after 1988/89, largely remaining between 3 and 4 kilograms. In the adjoining country of Malawi, where growth in fertilizer use on smallholder farms has been sluggish despite a somewhat better physical response (Lele, Christiansen, and Kadiresan 1989), very high relative fertilizer prices have obviously dampened growth in fertilizer consumption (Figure 3). During most of the 1980s, Zambia was able to maintain a favorable relative price environment. In 1989/90, real fertilizer prices increased by 81 percent. The average value-cost ratio declined to 3.13 for hybrid and 1.92 for local maize.

Comparing the relative price scenario in Figure 3 with fertilizer consumption data in Figure 1 shows that there was some correlation between the two. Fertilizer prices were rising from 1980/81 to 1983/84; fertilizer consumption was falling. When prices fell between 1983/84 and 1985/86, consumption rose. Since then, the correlation seems to have weakened. However, the post-1987 stagnation in fertilizer consumption in Eastern Province could be due to a lack of growth in national supplies. By 1985, the share of Eastern Province in national consumption had become so large that it could not be insulated from fluctuations in aggregate supply.

Because of changes in prices, the profitability of fertilizer use on maize has gone down; on local maize it is now marginal, a matter of serious concern because fertilizer use on local maize has been an important growth strategy for smallholder farms (see Chapter 8). For other crops, the situation is worse. Because of price changes, returns from fertilizer use dropped for cotton and soybeans (see Table 6). These crops, which offer some opportunities for diversification of the crop base of fertilizer use, do not receive the same kind of price support.

Increased efficiency assumes critical significance in the context of the new price regime. Apart from concerns about technical efficiency articulated earlier, there are two price-related factors that offer scope for improvement. First, in fixing prices for different fertilizer mixtures, the nutrient composition does not seem to be taken into account. For example, there is very little difference in the price of X (20-10-5) and D (10-20-10) compounds, although the latter has a significantly higher nutrient content. Moreover, D mixture has twice as much phosphate (P_2O_5)—a more expensive nutri-

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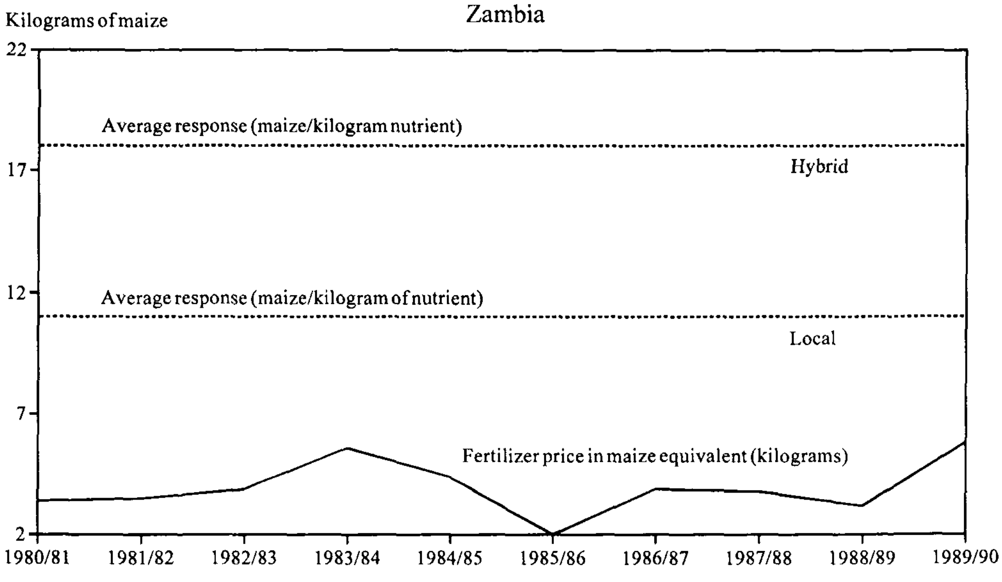
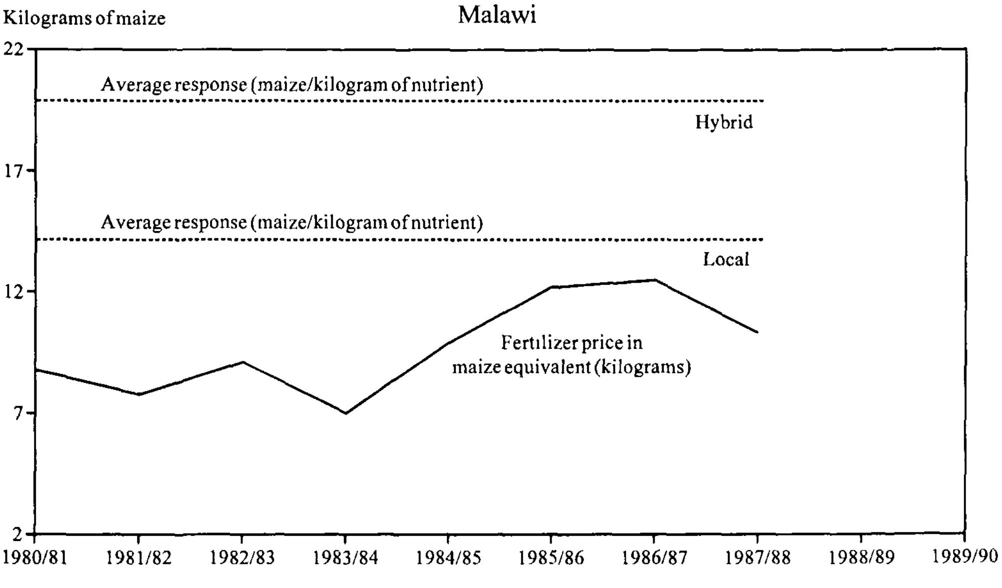
[9]Three combinations of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) (potash) are commonly used in Eastern Province. X compound is mixed in proportions of 20-10-5, D compound is 10-20-10, and C compound is 6-18-12.

[10]The average price per kilogram of plant nutrient was obtained by computing the price of nitrogen from the price of urea and the price per kilogram of nutrient for compound 10-20-10—the most commonly used fertilizers in Eastern Province—and averaging the two.

Figure 3—Fertilizer-maize prices in Zambia and Malawi





Sources: L. Mumeka, "Policy Constraints on the Development of Agriculture and Small-Scale Enterprises in Rural Zambia," in *Adopting Improved Farm Technology: A Study of Smallholder Farmers in Eastern Province, Zambia,* ed. R Celis, J. T. Milimo, and S. Wanmali, 62-92 (Washington, D.C.: International Food Policy Research Institute, 1991); and U. Lele, R. E. Christiansen, and K Kadiresan, *Issues in Fertilizer Policy in Africa: Lessons from Development Programs and Adjustment Lending.* Managing Agricultural Development in Africa (MADIA) Discussion Paper 5 (Washington, D.C.: World Bank, 1989).

ent in the international market. Rationalizing prices by basing them on real prices of nutrients would improve pricing efficiency.

Second, these differences have implications for fertilizer recommendations. Research results indicate that X compound (20-10-5) is the proper basal fertilizer to use for maize. Availability of this fertilizer in the province is restricted, D compound (10-20-10) is made available instead. In response to this supply constraint, the recommendation is modified to add more urea to make up for the lower nitrogen content of the D compound. At 1989/90 prices, these two recommendations are evaluated as follows:

$$\text{200 kilograms X + 150 kilograms urea} = (109N+20P_2O_5+10K_2O), \qquad (1)$$

which costs 2,684 kwacha (K) per hectare,[11] and

$$\text{200 kilograms D + 200 kilograms urea} = (112N+40\,P_2O_5+20K_2O), \qquad (2)$$

which costs K3,120 per hectare. (Prices for X, D, and urea were K0.383, K0.396, and K0.384 for each 50-kilogram bag, respectively).

Nonavailability of X implies that the fertilizer bill for the farmer is raised by 16 percent. Moreover, use of D compound leads to waste of P_2O_5 and K_2O because the proportions of those compounds are higher than needed. A recombination involving 100 D + 200 urea would provide 102N + $20P_2O_5$ + $10K_2O$ and would cost K2,328 per hectare, thus lowering the fertilizer bill by 14 percent, compared with the X-urea combination, and by more than 25 percent compared with the D-urea combination. More research is needed to find the best way of combining the two fertilizers, but this example clearly illustrates how greater economic efficiency can be generated. These changes are purely technical in nature. Addressing them would significantly improve the economic viability of fertilizer use and, to some extent, compensate for higher fertilizer prices.

Five major findings emerge from this description of the fertilizer response environment in Eastern Province.

- Information is still deficient on fertilizer responses in the valley region. Yet similar recommendations for fertilizer application on local maize, hybrid maize, and cotton are made for both regions.
- Even for the plateau zone, experiments with nutrients have been confined to some early work at Msekera. Researchers have mainly focused on nitrogen, the most deficient nutrient in Eastern Province soils, and have not investigated or analyzed interactions with phosphorous or potash (K_2O). Recommended levels of the latter two are perceived as maintenance levels. In the context of the new price regime confronting farmers, research on nutrient balance, which was not as crucial in the subsidized price environment that prevailed earlier, has to be given high priority. Researchers must focus on efficient nutrient combinations.
- On-farm trials on fertilizers have not really been successful in establishing site- and location-specific responses and recommendations in the plateau zone. Major conclusions are still drawn from trials at the Msekera Research Station.

[11]US$1.00=K35 in 1989/90.

Limited resources available to the ARPT for testing, such as on-farm fertilizer trials and soil testing, constrain this work.

- All recommendations pertain to pure-stand (sole) cropping situations. As long as farmers feel strongly compelled to use a mixed cropping system, there will be a need to evaluate fertilizer use strategies for this system.[12]
- The physical as well as the economic environment has contributed to high fertilizer use in the plateau region of the province. Despite recent increases in fertilizer prices, fertilizer use on hybrid maize remains profitable, although on local maize, its viability is threatened. For other crops, no attempt has been made to evaluate output prices in relation to fertilizer prices, perhaps because no fertilizer is used on these crops. Consequently, the profitability of fertilizer use is declining. Prices and marketing of crops other than maize will emerge as relevant issues in the future.

[12]Area under mixed cropping was found to vary from 11.1 percent of the total cultivated area in the Western Zone of the plateau to 49.1 percent in the Central Zone, 62.5 percent in the North/South Zone, and 47.4 percent in the valley, according to the survey on which this report is based. Higher security of output, symbiotic crop interactions, and the need for variety are the important rationales for mixed cropping in subsistence agricultural systems. As will be shown subsequently, fertilizer use is common under mixed cropping situations.

5

ADOPTION AND FERTILIZER USE PRACTICES

This chapter presents an overview of different dimensions of fertilizer use in Eastern Province, based on data from the sample households. Data on adoption, extent of area fertilized, and average rates of fertilizer application are presented in Table 7. Information is provided for 10 locations to reflect variability.

First, there is a sharp distinction between the plateau and valley regions. Sixty-seven percent of farmers in the plateau used fertilizers, against only 6 percent of those in the valley. The distinction is equally sharp for area fertilized and rates of application. The perception is that poor infrastructure and an inadequate fertilizer distribution network are the main factors responsible for low fertilizer use in the valley (ARPT 1986). Recent work based on the same data set on access to infrastructure reveals that infrastructure deficiencies exist in the valley zone (Wanmali and He

Table 7—Fertilizer use on smallholder farms in Eastern Province

Region/Zone Location	Percent of Farmers Using Fertilizers[a]	Percent of Cultivated Area Fertilized	Average Rate of Application[b]		Percent of Farmers Using Manure
			Per Cultivated Hectare	Per Fertilized Hectare	
			(kilograms/hectare)		
Plateau Region	67.1	55.6	53.6	96.4	1.2
North/South Zone					
Chipili	100.0	90.9	87 8	96 6	. .
Sinda	20.0	10.7	14.0	130.7	8.0
Chaweya	90 9	60.8	60.9	100.1	.
Kasendeka	87.9	68 4	78.7	115.0	.
Central Zone					
Makangila	93.9	80.8	83 3	103.1	. .
Mtenthela	53 6	45.6	36.8	80.8	.
Western Zone					
Chiwizi	25.8	18.0	13.4	74.4	3.2
Kamwala	45.1	49.2	31.0	63.0	. .
Luangwa Valley Region	6 3	5.2	3.5	66.9	. . .
Nkhoka	10.0	9.5	7.5	79.4	. . .
Mphata	3.0	2.8	1.2	42.2	. . .

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

Note: The ellipses (. . .) indicate a nil amount.

[a]This is a measure of the extent of adoption.

[b]The average rate of application is in kilograms of total plant nutrients ($N + P_2O_5 + K_2O$). Total quantity divided by the total cultivated area gives the average rate per unit of cultivated area The rate per fertilized hectare is obtained by dividing the total quantity by the area receiving fertilizer.

1989). However, as mentioned in the preceding chapter, because there is so little experimental evidence on fertilizer response, low or uneconomic response cannot be ruled out as a relevant factor explaining low use in the valley zone. Hybrid maize, the most fertilizer-responsive crop, is seldom grown in the valley. Therefore, the valley subsample has been excluded from subsequent analysis and discussion.

Average Fertilizer Use Indicators

The average rate of fertilizer applied per hectare of cultivated area in the plateau region—more than 53 kilograms of plant nutrients—is high by developing-country standards, and the average rate per fertilized hectare is even more impressive—96 kilograms. These high rates of application suggest that the extension service convinced the adopters that it was not worthwhile to use small quantities. Experimental work suggests a threshold level of 50-60 kilograms, below which no response is obtained (ARPT various years). The average rate of application per fertilized hectare was not lower than that at any location in the plateau region. This is an important finding, because most studies on fertilizer use in Asia, for example, indicate that rates of applications were not high in the early years of use. In Eastern Province, however, farmers have used the recommended amounts right from the beginning (Harvey 1973).

Data by locations (branches) reveal substantial variation. Among the plateau locations, adoption ranges from 20 to 100 percent, and the area fertilized, from 11 to 91 percent. The variation in rate of application per fertilized hectare is smaller: in four out of eight locations, the rate is over 100 kilograms of plant nutrients per fertilized hectare.

Looking at agroecological zones within the plateau, the indicators are low in the Western Zone, but even in the North/South Zone there are pockets of low fertilizer use. (North and South are combined for purposes of enumeration because results are similar.) In subsequent analysis, reasons for this spatial pattern are explored, and this evidence has obvious implications for fertilizer promotion (mainly research and extension) and distribution strategies within the province.

Finally, the last column of Table 7 shows that use of organic (cattle) manure has not been integrated as a fertility-enhancing strategy in the farming systems in Eastern Province. In only 2 out of 10 branches did a few farmers report this practice, although households do maintain cattle in all three major agroecological zones in the plateau region (see Table 2). Even where organic manure use was reported, the practice was to "kraal" (corral) the animals on the plot rather than to use decomposed cattle manure. Surveys carried out by the ARPT indicate that farmers perceived that increased weed infestation from the use of cattle manure was a major disadvantage (EPADP 1984). There was some use on intensively cultivated *dimba* (wetland) gardens. Manuring is a labor-intensive activity, which does not mesh with the relatively limited labor endowments of the region (Binswanger and Pingali 1988). The practice of burning weeds and other vegetative matter before planting was, however, common. Fallowing was practiced as a long-term fertility enhancement strategy under a bush-fallow system all over the province.

Although fertilizer use was practically nonexistent in the province before 1970, it reached about 54 kilograms per hectare in 15 years. This rate of growth is comparable to any recorded in high fertilizer-using pockets in developing countries (see, for example, Desai 1988). This rate and the fact that more than 55 percent of the cropped area receives fertilizer indicate that fertilizer use has become a well-established practice in the plateau. Use levels in this region of the province far exceed the national figure.

Allocation of Fertilizers

Experience in different developing countries indicates that, during the process of diffusion, fertilizer use spreads from high and more profitable responses and more profitable environments and crops to those with lower responses (Desai 1988; Desai and Gandhi 1990; Lele, Christiansen, and Kadiresan 1989). This seems to have been the pattern in Eastern Province also. A study by Harvey (1973) finds that fertilizer use was almost totally confined to the most fertilizer-responsive crop—hybrid maize—in the early 1970s.

Table 8, which provides data on the current pattern of fertilizer allocation in sample households and area shares of different crops in the plateau, clearly shows that fertilizer use is still largely confined to maize. Other crops are seldom fertilized. In contrast to the early 1970s however, the maize fertilization profile has changed. Fertilizer use has diffused to local varieties of maize and to mixed cropping situ-

Table 8—Allocation of area and fertilizer among crops on smallholder farms in the Eastern Province plateau region

Zone/Location	Local Maize (Sole)	Hybrid Maize (Sole)	Local Maize (Mixed)	Hybrid Maize (Mixed)	Other Crops
			(percent)		
Area allocation					
North/South Zone	7.6	15.0	51.7	10.4	15.3
Central Zone	14.9	19.4	42 1	5.8	17.8
Western Zone	55.6	18.8	6.7	4.3	14.6
Fertilizer allocation					
Plateau	12.6	39.3	33.0	14.8	0.3
North/South Zone					
Chipili	4.6	6.3	51.7	37.4	0.0
Sinda	0.0	49.5	50.0	0.0	0.5
Chaweya	28.0	35.1	30.3	6.6	0.0
Kasendeka	6.4	46.2	33.0	14.4	0.0
Central Zone					
Makangila	18.6	42.8	30.4	8.2	0.0
Mtenthela	8.8	43.5	47.6	0.0	0 1
Western Zone					
Chiwizi	33.4	57.1	0.0	0.0	9 5
Kamwala	14.2	69.2	3.9	12.7	0.0

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

Note: Fertilizer is in total plant nutrients ($N+P_2O_5+K_2O$).

ations, but the response in these situations is inferior to that for hybrids and single cropping. For the plateau region as a whole, about 46 percent of the fertilizer use is allocated to local maize, ranging in different locations from 18 percent to more than 58 percent. Similarly, nearly 48 percent of fertilizer is used on mixed crops ranging from 0 to 89 percent in different locations. Qualitatively, however, the fertilizer scene is still dominated by hybrid maize. Only about 25 percent of the total maize area in the plateau is devoted to this crop (against nearly 60 percent to local maize), yet its share in total fertilizer use is more than 54 percent.

The distribution of fertilizer between pure (sole) and mixed cropping situations also depends on the dominance of one or the other type of cropping. For example, mixed cropping is dominant in the North/South and Central zones (accounting for 48-62 percent of the cultivated area), and maize mixtures account for a substantial share of the total fertilizer used in these zones. In the Western Zone, where pure cropping is dominant, the opposite is true. It is important to note here the complete neglect of mixed cropping in agronomic research in general and fertilizer research in particular.

It is tempting to speculate about a diffusion path by relating the allocation behavior in Table 8 to the adoption data in Table 7. In the Western Zone, where fertilizer adoption is low, fertilizer use is concentrated on "better" response alternatives—57-82 percent of the fertilizer is allocated to hybrid maize and 83-90 percent goes to pure crops. At high adoption locations, on the other hand, use is more diffused. This supports the inference that in the initial stages of adoption, fertilizer is concentrated on crops where its use is most profitable.

Caution is, however, needed in equating adoption with use in any given season. The former concept represents the first overt step in acceptance of an innovation. Respondents to the survey were not canvassed to find out when they actually adopted fertilizer. Subsequent use or nonuse, as well as the pattern of allocation in any specific year or season, would depend on availability of funds to buy fertilizers and availability of fertilizer supplies. For example, even for a progressive farmer, nonavailability could result in concentration of limited supplies on hybrid maize only, or even nonuse in a specific season. It is, in fact, argued later that fertilizer use is so widespread in the plateau region that individual farmers are no longer constrained by lack of knowledge. Even those who do not grow hybrids now use fertilizers.

Adoption of fertilizer use is more pervasive than adoption of hybrid maize. The proportion of farmers growing hybrids varies from 31 percent to 43 percent between the three plateau zones (Table 2), whereas about 67 percent of farmers use fertilizers (Table 7). Less than 25 percent of the cultivated area is devoted to hybrid maize (Table 8), whereas fertilizer is used on about 56 percent of total area. Obviously, there are fertilizer users who do not grow hybrid maize. An examination of the distribution of maize fertilizer users in three mutually exclusive categories shows that 49 percent of those plateau farmers who used fertilizers on maize confined their use to local maize only. Only 8 percent used it exclusively for hybrid maize, and the rest fertilized both hybrid and local maize.

This result is surprising. A priori, one would expect that some farmers (early adopters as well as highly commercialized farmers) would use fertilizers only on hybrid maize, which is most fertilizer responsive, and others would use it on both hybrid and local varieties. Diffusion literature would suggest a "no-use → hybrid maize → hybrid + local → hybrid" continuum, depicting the transition to commercial agriculture. This pathway follows from the concept of a hierarchy of responses (Desai 1969), implying that the proportion of farmers using fertilizers on hybrid maize would be larger. Data show that 92 percent of the fertilizer-using households use it on local maize, as against 51 percent on hybrids (Table 9).

That such a large proportion of farmers fertilize only local maize calls for further examination of the characteristics of those farmers who currently use fertilizer but not on the most responsive crop—hybrid maize. A probit regression based on data for fertilizer-using households[13] shows a dependent fertilizer-use variable as dichotomous, having a value of unity for those households who fertilize *only* local maize and zero for those belonging to other categories (Table 10). The independent variable set includes the following:

- Personal attributes of the farmer: age, education, sex;
- Response characteristics: cultivated area, family size, oxen use, dependency ratio, cash sales, extension advice, credit; and
- Locational factors: agroecological zones.

Results indicate that farm size has a strong influence; farmers cultivating small areas are likely to be the ones who fertilize local maize. Households headed by females and older people and families having fewer dependents are also more likely to fall in this category. Those who fertilize local maize only are more likely to be located in the North/South Zone where fertilizer adoption is generally high (Table 7). Variables like education, capital, oxen use, and extension advice do not discriminate between the two groups of fertilizer-using households. These findings lend support to the point made earlier that knowledge regarding fertilizers is now widespread, particularly in areas where adoption is high, like the North/South Zone, and even traditionally disadvantaged farmers (small-scale farmers, women, and older farmers) use fertilizer on local maize. This group of fertilizer users is likely to be most similar to the subsistence-oriented nonuser. These are important findings and are pursued further in a broader context in Chapter 7.

Table 9—Allocation of fertilizer among crops for fertilizer users, Eastern Province

Crop Fertilized	Number of Households	Percent of Households
Hybrid maize only	10	8
Hybrid maize and local maize[a]	57	43
Local maize only	64	49
Total	131	100

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.
[a]Includes pure as well as mixed crops

[13]This can lead to sample selectivity bias (see Chapter 7).

Table 10—Probit regression explaining fertilizer use on local maize (probit maximum likelihood estimates)

Variable	Coefficient	t-Statistic	Mean
Constant	0.821	1.248	. . .
Age (years)	0.017*	1.572	41.33
Primary education (0,1, yes is 1)	−0.286	0.753	0.26
Secondary education (0,1, yes is 1)	−0.074	0.194	0.37
Female household head (1 is female)	0 649**	1.715	0.27
Dependency ratio (dependents/worker)	−0.526***	2.137	0.73
Family size (number)	0.058	0.959	5.84
Area cultivated (hectares)	−0.708***	4.649	3.13
Total farm sales (100 kwacha)	−0.001	0.123	12 73
Cultivation method (0,1, 1 is oxen)	−0.354	0.967	0.70
Extension advice (0,1, yes is 1)	0.311	0.949	0.30
Cooperative membership (0,1, yes is 1)	−0.016	0.045	0.25
North/South Zone (0,1, yes is 1)	0.645*	1.517	0.64
Western Zone (0,1, yes is 1)[b]	0.225	0.390	0 13
χ^2	74.850		
Number of observations	131		

Notes: The Central Zone is omitted.
*Significant at the 20 percent level.
**Significant at the 10 percent level.
***Significant at the 5 percent level.

Maize is the only crop that receives fertilizer in significant amounts. This implies that if relative fertilizer-maize prices and marketing conditions deteriorate,[14] fertilizer consumption could be adversely affected. Price manipulations of fertilizer relevant to maize in the mid-1980s have been careful (Figure 3): it was only in 1989/90 that price changes adversely affected the economic incentive to use fertilizer. Other cash crops being promoted to augment and diversify smallholder incomes in the province (for example, soybeans and sunflower) do not respond well to fertilizer application (Table 6) and, therefore, cannot help diversify the crop base of fertilizer use. Cotton is an exception. LINTCO, the parastatal agency responsible for all aspects of cotton promotion in the province, including extension, input supplies, and marketing, does not yet include fertilizer as part of the recommended package of practices for cotton, despite evidence from on-farm trials that fertilizer can result in significant responses and profits (ARPT 1986). Beans also offer some opportunities for diversification. This crop has not received adequate attention in development programs, including extension and marketing. Maize has been the center of attention for policymakers, and maize prices have been adjusted upward in recent years, often distorting relative output prices. For example, decline in production of groundnuts in Eastern Province has been attributed to this factor (Zambia, Ministry of Agriculture and Water Development, Planning Division 1983). As the maize production and supply situation improves at the national level, these issues will emerge as major constraints. It is

[14]Prices are officially fixed and maize purchases are handled by a parastatal company.

important to focus attention on crops like cotton and beans and to initiate fertilizer promotion programs for them.

Fertilizer Use on Crops

Disaggregated information on levels of fertilizer use by crops confirms the trends noted earlier (Table 11). Hybrid maize is almost always fertilized, regardless of whether it is grown in pure or mixed stands. This holds for all locations within the plateau region. Fertilizer use on local maize, on the other hand, is highly variable across locations, although, on average, 43 percent of the pure and 58 percent of the mixed stand local maize crops are fertilized.[15] Again, fertilizer use indicators in the Western Zone locations and at Sinda in the North/South Zone, are poor. These are relatively low adoption zones (Table 7). In these situations, almost the entire hybrid maize area is fertilized, but fertilizer use is constrained on local maize (Table 11), which is what one would expect during initial phases of adoption or when availability is limited. Another factor may be lower or uneconomic response to fertilizer use on local maize at these locations, but no data are available to test this possibility.

Rates of application are, as expected, significantly higher for hybrids than for local varieties and generally higher for pure crops than for mixed crops. The recommended rate of fertilizer application for hybrid maize in the plateau region is 140-170 kilograms of plant nutrients per hectare, depending on availability of different kinds of fertilizers. In most cases, actual application rates for hybrid maize planted alone are in this range. For local maize, on the other hand, actual rates are generally higher than the recommended 80 kilograms of plant nutrients, except in the Western Zone. The Research and Evaluation Unit Survey of Lundazi District (North Zone) also found that in 1982/83 farmers were using higher than recommended levels, and this was attributed to inefficient fertilizer application techniques (EPADP 1984). Data for 1985/86 show that at comparable locations (Chaweya and Kasendeka), rates for hybrid maize were not noticeably higher, but rates for local maize were, even though 1985/86 was a subnormal year in terms of fertilizer supplies to the province (Table 11) (EPADP 1987).

In order to provide firmer estimates of rates of fertilizer application (a number of estimates in Table 11 are based on too few observations), the data are aggregated at the level of agroecological zones (Table 12). The application rates, presented in terms of individual nutrients, are highest in the North/South Zone and lowest in the Western Zone. This is in line with the observed pattern of fertilizer consumption in the province (EPADP 1984). The major nutrient shortfall (in relation to recommended levels) is in nitrogen, particularly in the Central and Western zones. The actual levels of phosphate and potash are generally higher than recommended, again with the exception of the Western Zone. This is, as discussed in Chapter 4, related to the availability of correct fertilizer formulations in the province. The recommended mixture is X fertilizer (20-10-5), which contains a higher proportion of nitrogen, but

[15] The latter figure is misleading because location data show that the proportion of mixed crop area fertilized is higher than sole crop area at only one location (Makangila). At all other locations, the reverse is true.

Table 11—Percent of area fertilized and rate of application per fertilized hectare for important crops in the plateau region

Zone/Location	Percent of Crop Area Fertilized				Rate of Application[a]			
	Local Maize (Sole)	Hybrid Maize (Sole)	Local Maize (Mixed)	Hybrid Maize (Mixed)	Local Maize (Sole)	Hybrid Maize (Sole)	Local Maize (Mixed)	Hybrid Maize (Mixed)
					(kilograms/hectare)			
Plateau Region	43	97	58	98	74	119	87	106
North/South Zone								
Chipili	100	100	97	100	102	143[b]	86	112
Sinda	...	94	7	...	...	174[b]	99[b]	...
Chaweya	100	100	61	93	97	130	77	152[b]
Kasendeka	91	96	72	100	124	148	88	115
Central Zone								
Makangila	88	100	98	100	83[b]	96	109	125[b]
Mtenthela	74	91	49	...	47[b]	183	59	...
Western Zone								
Chiwizi	19	81	...	...	47	198[b]	...	...
Kamwala	28	99	20	100	31	77	66[b]	56[b]

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

[a]In kilograms of total plant nutrients ($N+P_2O_5K_2O$) per fertilized hectare.

[b]Based on less than five observations.

Table 12—Rates of nutrient application per fertilized hectare for major crops by agroecological zones in the plateau region

Crop	North/South Zone			Central Zone			Western Zone		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	(kilograms/hectare)								
Hybrid maize (sole)	96	33	17	74	27	13	61	16	8
	(109)	(20)	(10)	(109)	(20)	(10)	(109)	(20)	(10)
Local maize (sole)	68	25	12	49	17	9	32	4	2
	(66)	(10)	(5)	(66)	(10)	(5)	(66)	(10)	(5)
Hybrid maize (mixed)	75	26	13	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Local maize (mixed)	56	20	10	61	20	10	n.a.	n.a.	n.a.

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

Notes: Figures in parentheses indicate recommended levels. These are based on the most efficient recommendation using X (20-10-5) rather than D (10-20-10) fertilizer mixture (Table 3). Recommendations are not available for mixed crops.
n.a. is "not available."
N is nitrogen, P_2O_5 is phosphate, and K_2O is potash.

D mixture (10-20-10) is commonly supplied (EPADP 1986a). Use of this D mixture results in relatively higher than recommended application rates for phosphate and potash.

These tables suggest two major findings. First, there appears to be some scope for raising application rates for hybrid maize, particularly in the Western and Central zones. Availability and use of the correct fertilizer formulation may be the simple answer to this. Lack of the correct type of fertilizer not only reduces nitrogen levels, it also creates an imbalance in nutrient use. The extension service has obviously not been able to make farmers aware of the adjustments that need to be made when shifting from X to D fertilizer mixture. Second, the Western Zone, where all fertilizer use indicators are low, deserves special attention. More on-farm research on fertilizer is clearly needed in this zone.

Balanced Use of Plant Nutrients

Another way of looking at the question of using another fertilizer mixture when the correct one is unavailable is to examine whether farmers show a preference for a particular nutrient. There is, for example, evidence from Asia suggesting a neglect of nutrients other than nitrogen in an environment where nitrogen deficiency is the most critical problem (Desai and Gandhi 1989). The resulting imbalance threatens long-term fertility of the soil. In the plateau region, nitrogen is also the major nutrient deficiency; how the sample households address this problem is shown in Table 13.

In general, and in contrast to the Asian experience, farmers apply all three major nutrients. It should be noted that use of only nitrogenous fertilizers is not recommended (EPADP 1987). Generally, farmers follow a balanced pattern: only 8.5 percent of the households use only nitrogen and 5.7 percent of the fertilized area receives only nitrogen. Variations do exist from one location to another, however. For

Table 13—Use of plant nutrients, plateau region

Zone/Location	Percentage of Farmers		Percent of Fertilized Area	
	Using N Only	Using NPK	Receiving N Only	Receiving NPK
Plateau Region	8.5	91.5	5.7	94.3
North/South Zone				
Chipili	. . .	100.0	. . .	100.0
Sinda	25.0	75.0	10.0	90.0
Chaweya	3.3	96.7	0.7	99.3
Kasendeka	. . .	100.0	. . .	100.0
Central Zone				
Makangila	. . .	100.0	. . .	100.0
Mtenthela	46.7	53.3	34.8	65.2
Western Zone				
Chiwizi	50.0	50.0	92.1	7.9
Kamwala	7.1	92.9	4.1	95.9

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.
Notes: The ellipses indicate a nil or negligible amount; N is nitrogen, P is phosphorous, and K is potassium.

example, in Chiwizi and Sinda, both low-adoption areas (Table 7), a significant proportion of fertilizer users apply only nitrogen. The same is true in Mtenthela. At the other five locations, almost the entire fertilized area receives all three nutrients. These locational differences could be due to unavailability of basal fertilizer types. No data are available on this, although use and purchase patterns, and by inference availability of different kinds of fertilizers, are examined in the next chapter.

Farm Size and Fertilizer Use

The preceding sections have demonstrated that fertilizers are widely used in the plateau region of Eastern Province. But how uniformly are fertilizer use practices diffused within the smallholder sector? The interest here is in farm size. Literature on distributional consequences of new technology have focused on whether these technologies have any size bias.

Farm size distribution data are not available for Eastern Province as a whole. A small farm is customarily defined as less than 10 hectares in size, and about 96 percent of the farms in the province belong in this category. Table 14 shows the distribution of cultivated area of sample households in the plateau region and the corresponding fertilizer use in each size category within the smallholder sector. This section provides a descriptive summary and Chapter 7 addresses the question more rigorously.

Contrary to popular perceptions regarding land ownership in traditional agricultural systems in Africa, land distribution in the plateau region appears to be highly skewed. About 24 percent of the sample households cultivate less than 1 hectare of land, and their share in the total cultivated area is only about 6 percent (Table 14). At

Table 14—Fertilizer use by farm size, plateau region

	Farm Size Classes (in Hectares)				
Item	Less than 1	1.1 - 2.0	2.1 - 3.0	3.1 - 5.0	More than 5
Percent of households	23.9	31.6	15.4	18.6	10.5
Percent of total area	5.8	18.6	15.0	28.2	32.4
Percent of maize area under hybrids	3.1	15.1	17.6	24.2	49.2
Percent of farmers using fertilizers	51.7	67.9	65.8	67.3	100.0
Percent of area fertilized	45.5	47.5	51.2	41.3	70.7
Kilograms of nutrients[a]/fertilized hectare	102.5	92.2	94.6	104.5	93.9
Fertilizer allocation (percent)					
Local maize (sole)	28.1	14.2	7.1	11.6	11.9
Local maize (mixed)	59.4	47.5	54.3	26.7	21.1
Hybrid maize (sole)	5.5	27.2	20 9	41.8	52.6
Hybrid maize (mixed)	5.5	9.0	17.7	19.9	14.4
Other crops	1.5	2.1	...	.	...

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia

[a]Total plant nutrients ($N+P_2O_5+K_2O$).

the other extreme, only 10.5 percent of the households cultivate more than 5 hectares, but they control 32 percent of the total area. Fertilizer use information shows that there is not much difference between size categories in rate of adoption, percent of area fertilized, and rate of application on farms up to 5 hectares. Farms in the smallest category (less than 1 hectare) have marginally lower rates for adoption and area fertilized. The average levels on smaller farm-size categories suggest fairly high fertilizer use—one-half to two-thirds of the households use fertilizer and about half the cultivated area is fertilized at an average rate of about 100 kilograms of total plant nutrients per hectare.

On farms of more than 5 hectares, adoption is universal. About 71 percent of the cultivated area receives fertilizer at a rate of 94 kilograms per hectare. These farms are clearly more commercialized. For rate of application, however, no trend is discernible between the different farm categories.

The pattern of fertilizer allocation to crops, however, changes with farm size. In the smallest category, more than 87 percent of fertilizer is allocated to local maize; on farms of more than 5 hectares, hybrid maize accounts for 67 percent of the total fertilizer used. As farm size increases, there is also a tendency to allocate more to sole crops than to mixed crops of maize. These patterns could be related to relative land scarcity and food requirements at the household level. Farmers concentrate on local maize for their food needs; hybrid maize is mainly grown as a cash crop. To meet their food requirements from a meager land base, farmers in the smaller size classes allocate larger shares of their cultivated area to local maize varieties and use fertilizer to obtain higher yields. It has been empirically demonstrated in Table 10 that smaller farmers dominate the category that uses fertilizer on local maize. A small amount of cultivated area also implies more mixed cropping to meet the need for variety in food. These constraints are not binding on larger holdings, where adoption of hybrids is much higher (Jha, Hojjati, and Vosti 1991).

This is an important finding. It has been argued that yield-increasing technologies do not mesh well with a land-surplus farming system unless infrastructure and market conditions make it profitable to produce surpluses that can be sold (Binswanger and Pingali 1988). Hybrid maize in Eastern Province illustrates this case. However, this report shows that even very small farmers who are primarily subsistence-oriented find it worthwhile to use fertilizers (Table 10). When fertilizers generate high responses, they represent a viable option for small farmers. By raising the possibility of surplus production (and command over more labor resources), fertilizer use facilitates a medium- to longer-term transition to larger farms and greater commercialization. An attempt is made in Chapter 8 to elaborate on this theme and to test this proposition empirically.

6

FARMERS' ACCESS TO FERTILIZERS

Farmers' fertilizer use decisions and practices are also influenced by fertilizer supply and distribution conditions. Availability of the right kinds of fertilizers at the right time and at accessible locations is crucial. Access is also constrained by inadequacy of working capital in subsistence-dominated agricultural systems. Processes such as distribution systems, credit, and procurement are still evolving in most developing countries. In the Zambian context, fertilizer procurement and distribution are handled by the state through parastatals or cooperatives.[16] The latter are also the main source of institutional credit for smallholders.[17] There is no private-sector involvement. Unfortunately, no data were collected on the existence, scale, or operation of these institutions in the study locations. Therefore, inferences are drawn from observations of the extent to which the sample households interact with institutions. For example, availability of fertilizer is judged by farmers' purchases of different kinds of fertilizer and the timing of these purchases. Access is evaluated on the basis of use of credit, distances, and modes of travel.

Use of Major Fertilizer Materials

Several fertilizer mixtures are available in Zambia. These are meant to be used for basal application at or soon after planting. Research done in Eastern Province found X compound (20-10-5) to be the most effective basal fertilizer. Urea is recommended as the nitrogenous fertilizer for top dressing. The fertilizer materials actually used by the sample farmers during 1985/86 are presented in Table 15.

Almost the entire quantity of basal fertilizer used by sample farmers consisted of D compound (10-20-10), and only urea was used for top dressing. The Eastern Province Agricultural Development Project (EPADP) staff and scientists of the Adaptive Research Planning Team (ARPT) have consistently emphasized the need for X compound, but the distribution system has not been able to respond, primarily because assessment of demand for different components at the national procurement level has been faulty (Eastern Province, Department of Agriculture 1986). Though unit prices for both these formulations are about the same, substitution of D compound for X necessitates revision of the recommendations (increasing the quantity of

[16]In 1985/86, the National Agricultural Marketing Board (NAMBOARD) was responsible for procurement of fertilizers and participated in distribution along with cooperatives. Subsequently, this institution was abolished and cooperatives assumed most of NAMBOARD's functions.

[17]Commercial banks and the Lima Bank are other institutions that provide credit. The Lima Bank is a public agricultural bank, established in 1987 through the amalgamation of the Agricultural Finance Company and the Zambia Agricultural Development Bank.

Table 15—Use of different kinds of fertilizers, plateau region

Zone/Location	Mixed Fertilizers			
	D Compound (10-20-10 NPK)	X Compound (20-10-5 NPK)	R Compound (20-20-0 NPK)	Urea (46N)
	(50-kilogram bag)			
Plateau Region	978.0	27	4	1,028 5
North/South Zone				
Chipili	170.5	4	. . .	176.0
Sinda	13.0	11	2	22.0
Chaweya	122.0	4	. . .	118.0
Kasendeka	340.0	3	. . .	342.0
Central Zone				
Makangila	226 0	2	2	212.0
Mtenthela	21.5	3	. . .	31.5
Western Zone				
Chiwizi	9.0	. . .	. . .	48.0
Kamwala	76 0	. .	. . .	79.0

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

Note: The ellipses (. . .) indicate a nil or negative amount.

urea) and raises the effective cost for the farmer (as mentioned in Chapter 4). In addition, use of D compound wastes phosphates.

Generally, a one-to-one relationship is maintained between materials meant for basal and top dressing (Table 15). This is what one would expect because the recommended combination is usually in this ratio, and at most locations, farmers are able to maintain this level of application. This suggests that both these types of fertilizers are available. The exceptions are Chiwizi and Mtenthela, where availability of basal (mixed) fertilizer was limited. It may be noted that at these locations farmers were fertilizing a substantial area with a single nutrient, nitrogen, coming from urea, which was the major fertilizer available (Table 13). This imbalance should be attributed to inefficient supply conditions rather than inadequate knowledge. Clearly, unavailability of the right kind of fertilizer is a constraint resulting from poor coordination between the Department of Agriculture and NAMBOARD (leading to procurement and supply of an inefficient fertilizer formula to the province), and logistic failures in the distribution system (leading to supplies that do not reach all locations).

Time of Fertilizer Purchase

The issue of timely availability is examined by looking at the fertilizer purchase patterns of farmers at different locations. Monthly expenditures of the sample households were monitored from November 1985 to December 1986. From these records, expenditures on fertilizer purchase were retrieved for each household. Table 16 shows the monthly distribution of total expenditure on fertilizers. The planting season starts in November and extends to January. This is the period for basal application; top dressing extends to March.

Table 16—Monthly fertilizer purchase patterns of farmers

Zone/Location	Percent of Total Fertilizer Expenditure			
	December	January	February	March
North/South Zone				
Chipili	92.6	...	7.4	...
Sinda	38.8	61.2	...	...
Chaweya	84.6	10.9	4.5	..
Kasendeka	47.4	52.6	...	
Central Zone				
Makangila	100.0	...	...	...
Mtenthela	11.0	33.3	55.7	..
Western Zone				
Chiwizi	72.0	16.0	8.6	4.4
Kamwala	100.0	...	...	...

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Council, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

Note: The ellipses (.) indicate a nil or negative amount.

All fertilizer purchases were confined to the November-March period.[18] At four out of eight locations, more than 80 percent of the purchases were made by December. At these locations, fertilizer was obviously available at the right time. At two locations, Mtenthela and Chiwizi, significant purchases were made in February or March. By then, it is too late for basal application and late even for top dressing. Supplies were apparently not timely in those locations. These late purchases were obviously for the top-dressing fertilizer—urea. As was shown earlier, the rate of adoption is low at these locations (Table 7) and nutrient use is not well balanced (Table 13). These problems were also noted at Sinda, where very little fertilizer (39 percent) was purchased by the end of December, the most critical period for fertilizer application.

These data suggest that at some locations fertilizer use indicators could be low because of the unavailability of the right kind of fertilizer or untimely delivery of supplies. The latter is more critical for basal fertilizers because the time constraint is more binding. Top dressing with urea can be done up to 5-6 weeks after planting, but basal application cannot be delayed beyond 2-3 weeks after planting. To the extent that the delays in fertilizer purchases are not voluntary, they reflect problems in the fertilizer delivery system, which arise from institutional constraints. For example, there may be delays in processing credit applications, or supplies from the main depots may arrive late. These cannot be categorically addressed with data from this survey.

It is important to mention that delayed fertilizer application (and the consequent inefficiency in fertilizer use) does not occur due to delayed availability alone. Even

[18]The survey did not cover the period September-October 1985, but this period was monitored in 1986. In that year as well, fertilizer purchases started in November and not earlier. Thus, information presented in Table 16 covers the entire fertilizer purchase season.

in areas where availability and timing problems do not exist, fertilizer application could be delayed due to labor constraints (ARPT various years). Highest priority is accorded to planting operations during November and December, leaving farmers very little time for operations like fertilizer application and weeding, which could be delayed or inefficiently done or both. The recommended practice of basal fertilizer application (making a hole 7.5 centimeters deep, 7-8 centimeters away from the plant, applying a measured quantity of fertilizer, and covering the hole) is a fairly labor-intensive operation, especially for hoe farmers.

It was not possible to empirically demonstrate this on the basis of the survey because of data problems.[19] Nevertheless, the following results are indicative. It was assumed that basal fertilizer application about a month after planting would reflect correct timing. The proportion of fertilized plots on which the timing of basal application fell within this time band was as follows: Chipili, 6 percent; Sinda, 71 percent; Chaweya, 71 percent; Kasendeka, 11 percent; Makangila, 98 percent; Mtenthela, 0 percent; Kamwala, 10 percent; and the average for the plateau region, 37 percent. Thus, in four out of seven locations, there was ample indication that the timeliness of this operation was suboptimal.[20] Two of these, Chipili and Kasendeka, were locations where the rate of adoption and other fertilizer use indicators were high (Table 7).

On the agricultural research side, the labor-constraint-induced delays have been addressed in three ways (ARPT various years). First, instead of two applications (basal and top dressing), only one application of basal and top fertilizers has been tested and recommended. Second, experiments have been conducted to show that top dressing with urea can be deferred until 7-8 weeks after planting without detrimental yield effects. Neither of these findings, however, helps alleviate the labor constraint at the critical period during November-December. In fact, the first aggravates the early-season labor bottleneck. Finally, attempts have been made to identify maize varieties and hybrids that require shorter periods to reach maturity and therefore can be planted late. This would enable farmers to spread their operations over time and reduce peak-period labor requirements.

Technical efficiency in fertilizer use practices has been identified as a major extension theme. Surveys conducted by ARPT have shown that farmers' practices are inefficient in terms of quantity applied per stand (many farmers use a "handful" measure that results in uneven application over the field), method of fertilizer application (application on surface or uncovered holes), nutrient balance (only top dressing with urea), and timing of application. These have been identified as the reasons why, despite high absolute levels of fertilizer use, hybrid maize yields remain below the potential (EPADP 1984). Now that profitability of fertilizer use has been significantly eroded by removal of subsidies, the major thrust for extension services should be to remove these sources of technical inefficiency.

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[19]Dates of different operations on each cultivated plot were obtained in a one-shot crop management survey toward the end of the season. While critical operations like planting were easily recalled, dates of other operations reported by farmers were likely to be less reliable.

[20]These results are also reported in ARPT 1986. The survey, conducted in the South Zone of the plateau, showed that 40-60 percent of the farmers did not apply basal fertilizer at the right time. Note also that data on timing of operations were not available for Chiwizi.

Access to Fertilizer

Traditional farming is characterized by very low capital intensities. To ease the transition to modern agriculture, almost all agricultural development projects, therefore, emphasize developing and strengthening credit institutions to provide working and investment capital for purchase of modern inputs. The cooperative sector and commercial banks are extending credit to smallholders in the province for purchase of short-term production inputs (Banda 1991). Based on data from the study survey, Table 17 provides information on the spread of institutional credit and the extent to which fertilizer users in the plateau region depended upon borrowed funds for fertilizer purchases.

Only 15 percent of the sample households in the plateau region used institutional short-term credit in 1985/86, a figure not very different from the estimate of 17 percent for 1984/85 projected by an earlier survey in the province (EPADP 1986b). Data for different locations indicate that, at best, about one-third of the households were covered (Chipili and Mtenthela). On the other extreme, in Sinda and Chiwizi none of the farmers used any institutional credit. The coverage is not only thin, it is also highly uneven.

More significantly, Table 17 shows that most of the fertilizer users do not use institutional credit. Less than one-fourth used credit, on average, although at some locations (notably Mtenthela), the figures are high. This indicates that the majority of fertilizer users depend on their own funds or informal credit sources for fertilizer purchases. Comparing these figures with those on the extent of adoption of fertilizers in Table 7, it appears that locations where adoption of fertilizer was high did not necessarily have a high proportion of farmers depending on credit. On the other hand, at locations where adoption was poorest (Sinda and Chiwizi), access to credit was also poorest. At locations in the intermediate adoption range (Kamwala and Mten-

Table 17—Credit and fertilizer use, 1985/86

Zone/Location	Percent of Farmers Obtaining Credit from Institutional Sources	Percent of Fertilizer Users Obtaining Credit from Institutional Sources
Plateau Region	15.2	23.8
North/South Zone		
Chaweya	9.1	10.0
Kasendeka	6.1	6.9
Chipili	36.4	36.4
Sinda	0.0	0.0
Central Zone		
Mtenthela	37.5	80 0
Makangila	12.1	12 9
Western Zone		
Chiwizi	0.0	0 0
Kamwala	18.8	42.8

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

thela), however, dependence on credit was high. At these locations 43 and 80 percent of the fertilizer users, respectively, were borrowers. This suggests that credit support is perhaps crucial in the early stages of fertilizer diffusion. This initial support helps to generate surpluses that can then be reinvested by farmers for more fertilizer purchases or area expansion or cultivation of hybrid maize. This is the pathway encouraged by EPADP. These inferences are tentative, however. It has been shown earlier that at some locations (Sinda and Chiwizi) there were also fertilizer distribution problems. Obviously, low use at these locations cannot be attributed to credit constraints alone. This theme is pursued more rigorously in the succeeding chapters.

Credit eases the financial constraint to access, but in poorly developed regions, there are physical barriers to access as well. Roads and transport facilities near the settlements may be inadequate, making market towns inaccessible. Inadequate facilities also raise the real cost of fertilizers if time and effort dimensions are considered. The modal distance traveled to purchase fertilizers varies from less than 1 kilometer at Sinda to nearly 9 kilometers at Chiwizi (Table 18). The apparent relationship between distance and fertilizer adoption at these locations appears to be weak (Table 7), but in three out of four low-adoption locations—Chiwizi, Mtenthela, and Kamwala—farmers have to travel long distances to purchase fertilizers. The fourth location, Sinda, is an exception. It has the lowest adoption level, yet the fertilizer sales point is less than a kilometer away. Nevertheless, a study on access to and use of different services, based on the same data set, showed that distance was an important determinant of fertilizer purchases (Wanmali and He 1989).

Table 18 also shows that motorized transport is used in only two out of eight locations. This reflects the nature of the road network. Ox carts, or in Lundazi, boats or canoes, are generally used to transport bulky inputs. Oxen and cart ownership is

Table 18—Average distance and mode of transport used for fertilizer purchases, 1985/86

Zone/Branch	Average Distance Traveled	Percent of Trips Made			
		Foot	Ox Cart, Boat, or Canoe	Motorized Transport	Bicycle
	(kilometers)				
North/South Zone					
Chipili	2.15	11	84	. .	5
Sinda	0.72	56	22	.	22
Chaweya	1.78	21	74	. . .	5
Kasendeka	3.76	7	90	.	3
Central Zone					
Makangila	2.30	11	78	11	. . .
Mtenthela	4 33	12	70	18	. . .
Western Zone					
Chiwizi	8.67	67	. . .	. .	33
Kamwala	2.63	. . .	100	.	. . .

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.

Notes: Figures pertain to the most frequently used purchase location in each branch The ellipses (. . .) indicate a nil amount.

limited and, in spite of a rental market, farmers' access to this mode of haulage is restricted. In some areas where ox carts are not available (for example, Chiwizi), farmers have to walk or use bicycles. This obviously limits the volume of fertilizer that can be transported.

Data presented in this chapter indicate wide variations in financial conditions and physical access to fertilizers within the province. There are indications that these have an effect on fertilizer use. In the econometric analysis attempted in the next chapter, the impact of these variables is examined in greater detail.

7

DETERMINANTS OF FERTILIZER USE

As articulated in Chapter 2, the process of fertilizer diffusion is governed by four sets of forces: the nature of the physical response environment, factors responsible for creating effective demand for fertilizers at the farm level, the status of the fertilizer distribution system, and conditions of aggregate supply of fertilizer at the national level. Some of these lie in public domain (for example, prices and marketing, fertilizer production, imports and distribution, research, extension, education, and credit) and others relate to agroclimatic conditions and characteristics of the farm or the farmer (such as education, age, experience, subsistence priorities, and farm resource endowments).

In a cross-sectional, household-level data set, only a part of these processes can be captured. Effects on fertilizer use decisions of household-level variables like education, farm size, size and composition of family, age, gender, and household participation in credit and extension programs can be analyzed. Also, since the households are spread throughout the province and the locations vary on access to institutions and markets and agroecological conditions, these factors can also be brought in to explain differences in fertilizer use decisions. Other factors, such as the incentive environment, aggregate supply situation, and availability of new technologies that shift the fertilizer response curve, are fixed in the short run, and their effects cannot be deciphered from this kind of data set.

Some information on these fixed factors has been provided in the preceding chapters. For example, it has been shown that in the plateau region, the dominant crop of the farming system—maize—is highly responsive to fertilizer. Availability of suitable hybrids further improves the agronomic potential of fertilizer use. It has also been shown that the relative fertilizer-output price ratio has historically been conducive to growth in fertilizer use (Chapter 4). Thus, regarding incentives and supply, the plateau region was favorably placed in 1985/86 for widespread adoption of fertilizer. Regarding credit and infrastructure, however, some constraints were noted at certain locations in the plateau, as well as in the valley. These obviously exert a dampening influence. No information was available from the survey on the fertilizer distribution system, though deficiencies in timing of supplies and types of fertilizer materials available were observed that may be attributed to inadequacies in the distribution system (see Chapter 6). Finally, aggregate supplies at the national level seem to have constrained fertilizer use in Eastern Province in the second half of the 1980s. Problems with assessment of demand for different kinds of fertilizer were also noted. These findings provide the context within which results of the econometric exercise reported in this chapter need to be interpreted. These econometric analyses aim at rigorous assessment of the effects of sociocultural, institutional, and environmental factors on fertilizer use decisions of individual smallholders.

Theoretical Framework and Model

First, farmers decide whether they will use fertilizer (USEFERT). Second, they make a decision regarding intensity of use, represented here by the rate of fertilizer application per hectare (NPKFHA). Factors explaining both these decisions are identical, since both are generated from the same underlying decisionmaking process.

An econometric problem that arises in estimation of these relationships is sample selectivity bias. This is relevant for the intensity of use variable, but it is not observed for the sample as a whole. By excluding individuals who do not use fertilizers, the dependent variable is censored and the residuals do not satisfy the condition that the sum of the residuals must equal zero (Maddala 1977). This problem is handled in this study by using the Heckman method, which consists of two steps (Heckman 1974; 1980). First, USEFERT is estimated by using a likelihood function on both fertilizer users and nonusers. Then probit is applied to maximize this function.[21] From the probit equation the inverse of the Mill's ratio, LAMBDA (λ), which is the ratio of the ordinate of a standard normal to the tail area of the distribution, can be computed (Heckman 1980). The Mill's ratio reflects the probability that an observation belongs to the selected sample. In the second step, λ is included as an additional variable in the ordinary least squares estimation of the intensity equation (NPKFHA) for fertilizer-using households. This technique eliminates the potential sample selection bias. If λ is not statistically significant, then sample selection bias is not a problem (Heckman 1979; 1980).

The estimated models in this study are defined as follows:

Probability of fertilizer use (USEFERT) is

$$\text{Prob (USEFERT=1)} = 1 - F(-\gamma X), \quad (3)$$

and intensity of fertilizer use (NPKFHA) is

$$\text{NPKFHA} = \beta_0 + \beta_1 X + \beta_2 \lambda + \varepsilon, \quad (4)$$

for USEFERT > 0, where X is the vector of the regressor and λ is the inverse of the Mill's ratio. β_i and γ are vectors of unknown coefficients, and ε is the new residual with the property that $E(\varepsilon)=0$ (Maddala 1983).

It is hypothesized that the two decisions (USEFERT and NPKFHA) are influenced by the following set of variables:

1. Personal attributes of the farmer: age, level of education, sex, family subsistence pressure;
2. Farming system and resource characteristics: cultivated area, family size, use of oxen, hybrid maize cultivation, and liquidity position of the farmer;
3. Institutions and infrastructural factors: access to credit, extension advice, market and fertilizer supply situations; and
4. Environmental factors: agroecological zones.

The variables used in this analysis are defined in Table 19. Although the terms "fertilizer use" and "adoption" have largely been used interchangeably in this report,

[21]For a description and discussion of the probit model, see, for example, Maddala 1983, 22-27.

Table 19—Definitions of variables in the fertilizer use regressions

Variable	Definition	Mean[a]	Standard Deviation
Dependent variables			
USEFERT	Use = 1; nonuse = 0	0.67	0.47
NPKFHA	Total nutrient used per fertilized hectare	68.79	63.72
Personal attributes			
AGE	Age of the household head (years)	43.24	14.97
HEADHH	Sex of household head (male = 0, female = 1)	0.32	0.47
EDP[b]	Up to 5 years of schooling (0, 1, yes = 1)	0.25	0.43
EDS[b]	More than 5 years of schooling (0, 1, yes = 1)	0.33	0.47
DRATIO	Number of dependents[c]/number of adults	0.73	0.60
Resource characteristics			
AREAHA	Cultivated area in hectares	2.69	2.48
CULTMETH	Oxen use (0,1, yes = 1)	0.64	0 48
FAMILYSZ	Number of persons in the family	5.91	3.08
USEHYM	Adoption of hybrid maize (0,1, yes = 1)	0.36	0.48
ANCR	Total farm sales (100 kwacha)	9.21	17.40
Institutional access			
CDD	Distance to fertilizer market (kilometers)	15.60	9.37
COOPMEM	Membership in a cooperative (0, 1, yes = 1)	0.19	0 39
ADVICE	Receipt of extension advice (0, 1, yes = 1)	0.27	0.44
SDUM	Fertilizer supply (0, 1, 1 for Sinda, Kasendeka, Mtenthela, and Chiwizi)	0.46	0.50
Environmental factors			
Z_2, Z_4	Dummy variables (0,1) for North/South and Western zones		

[a]Based on 199 plateau households.
[b]"Illiterate" is excluded from the education category, and the Central Zone is excluded from the zone categories.
[c]Dependents are defined as persons below 14 years and those over 60 years.

USEFERT does not measure adoption in a strict sense. The education variables, EDP and EDS, give better access to information about the new technology. Thus, the education of the head of the household is expected to have a positive impact on the decision to use fertilizer. Older farmers are less likely to adopt a new technology, and this is expected to have a negative effect.

The status of women-headed households has received considerable attention, and such farms are generally perceived to face more constraints than others. They also are more subsistence-oriented (see, for example, von Braun, Puetz, and Webb 1989; von Braun and Pandya-Lorch 1991). Nearly one-third of the sample households are headed by women, as indicated by the variable, HEADHH.

The more dependents in a family the greater the pressure to provide subsistence crops; the variable DRATIO was included to capture such effects. On the one hand, a large family creates more consumption pressure, and, on the other, a larger supply of labor is expected to affect adoption rates favorably. Thus, it is hypothesized that the more intense the subsistence pressure, the greater will be the tendency to adopt the new technology.

Adoption of hybrid maize (USEHYM) is expected to affect the use of fertilizer positively. As was shown earlier, fertilizer and hybrid maize go together (Table 11). The economic status of farmers (usually measured as wealth) exercises a positive influence. In the absence of wealth data, and in the context of African smallholder farming systems, the area (AREAHA) and oxen use (CULTMETH) variables capture this effect.[22] The shortage of working capital can also be a major constraint to adoption of the new technology. In this analysis, value of sales of crop and livestock products during the year (ANCR) has been used as a proxy for farmer's liquidity, which is expected to have a positive influence on adoption.

Influence of credit is measured in terms of membership in cooperatives (COOPMEM). Fertilizer is promoted by cooperatives. If the farmer is a member of a cooperative, credit and fertilizer are provided as a package. When the farmer buys fertilizer, the loan for the purchase is granted simultaneously. Thus, membership in a cooperative is very important in the adoption of fertilizer. Having access to other sources of credit may not have much effect on purchase of fertilizer, because a farmer may not know where to buy fertilizer. Of course, membership in a cooperative also indicates higher socioeconomic status.

Extension contact (ADVICE) is measured by the household's contact with an extension agent during the year. It is expected to have a positive effect on fertilizer use. Market access is defined as a location-specific variable and is defined as the mean distance that a farmer travels to purchase fertilizer (CDD). As the distance to market increases, the purchase of fertilizer is anticipated to decrease. Fertilizer supply conditions are also measured in location-specific terms. In Chapter 6, four locations (Sinda, Kasendeka, Mtenthela, and Chiwizi) were identified as having problems with fertilizer supplies (SDUM). Thus, unavailability of fertilizer is anticipated to have a negative influence on adoption. Finally, agro-ecological differences are accounted for by using dummy variables for the three low zones (Z_2 and Z_4) (see Chapter 3). Those zones that consume little fertilizer are expected to have a negative influence. Full and consistent information on this set of variables is available only for 199 (out of 262) sample households in the plateau region. Table 19 and all other subsequent analyses are based on these 199 observations.

Using equations (3) and (4), the empirical model may be specified as

$$\text{USEFERT} = f(\text{AGE, HEADHH, EDP, EDS, DRATIO, AREAHA, CULTMETH, FAMILYSZ, USEHYM, ANCR, CDD, COOPMEM, ADVICE, SDUM}, Z_2, Z_4), \text{ and} \quad (5)$$

$$\text{NPKFHA} = h(\text{AGE, HEADHH, EDP, EDS, DRATIO, AREAHA, CULTMETH, FAMILYSZ, USEHYM, ANCR, CDD, COOPMEM, ADVICE, SDUM}, Z_2, Z_4, l). \quad (6)$$

Thus specified, the model still has a problem. None of the right-hand side variables used in equations (5) and (6) are truly independent or exogenous. For example, it has been shown (in Table 11) that hybrid maize and fertilizer go together: farmers seldom adopt hybrid maize without adopting fertilizer use. Also, in the land-surplus context of Eastern Province, depending upon the farmers' ability to hire more labor or oxen during planting time, cultivated area can be expanded. Both options for

[22]Number of cattle was also tried but it did not prove satisfactory.

increasing output (expansion of cultivated area and use of yield-increasing inputs like hybrid maize and fertilizers) are available to farmers, and both should be treated as endogenous.

In subsequent analysis, an approach combining an instrumental variable and the Heckman approach is used to address these problems. First, AREAHA and USEHYM equations are estimated and the predicted area and hybrid maize adoption variables are employed as instruments in the fertilizer use and intensity equations. The NPKFHA equation is only estimated for fertilizer-using households.

Thus, AREAHA, USEHYM, USEFERT, and NPKFHA form the endogenous variable set, and the others (described in Table 19) are treated as exogenous. An additional variable, SETFMYRS, which determines how long the household has resided at the present location, has also been included in the instrumental variable equations. A longer stay provides time to acquire more land and higher socioeconomic status (von Braun, Puetz, and Webb 1989). Since labor availability is crucial for area expansion, another variable, LOFFEMP, measuring hours of off-farm work per household (in 100-hour units), was also considered in these equations. The system is estimated simultaneously and the results are presented in Table 20.

The area and hybrid adoption equations (used as instruments in the fertilizer equation) provide some interesting insights. None of the personal attributes have any influence on area. All farmers share the desire to acquire more land and produce more. Larger labor supply, indicated by larger family size, access to oxen, and higher liquidity level (which allows access to hired labor and oxen) are important in realizing this goal. Longer duration of stay at one site is also land-augmenting in the sense that some land can be cleared every year and land stock can be cumulatively augmented.[23] Among institutional factors, better access to markets and credit also encourages area expansion. The odd result here is the negative coefficient for DRATIO. Adoption of hybrid maize, however, is influenced by personal attributes—older farmers and female farmers are reluctant to adopt. Larger family size, higher liquidity level, and access to oxen affect adoption favorably, as do access to credit and markets. Decline in family labor supply due to off-farm work inhibits adoption of hybrid maize.

For fertilizer use, the variables age, liquidity, fertilizer supply, credit, and market access emerge as significant. None of the others (including personal and institutional factors) affect this decision. Current fertilizer use and adoption of hybrid maize decisions are independent of farm size. Consistent with earlier results, adoption in the Western Zone is poor. These findings lend support to the view articulated in Chapter 5 that farmers in the plateau region are now well aware of the benefits of fertilizer use. Farmers' liquidity, access to credit, and market infrastructure, as well as a functioning distribution system, are the major factors determining use or nonuse of fertilizer in any particular year.

The predictive power of the equation explaining intensity of use was very low. Farmers in the Western Zone used lower levels of fertilizer. A higher level of education and access to oxen led to higher fertilization rates. The education result is important when the intensity of fertilizer application is considered, but not in the decision of whether to use fertilizer. A decision on how much fertilizer to use requires

[23]This works even in a bush-fallow system where land is cultivated for six-to-seven seasons and then fallowed.

Table 20—Determinants of fertilizer use and intensity

	Estimation of Instruments				Fertilizer Use Decisions			
	AREAHA[a]		USEHYM[b]		USEFERT[b]		NPKFHA[a]	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	0.060	0.082	−0.355	0.645	2.486***	3.563	83.459	3.840
AGE	−0.007	0.638	−0.022***	2.446	−0.028***	2.705	−0.437	1.229
HEADHH	−0.188	0.566	−0.382*	1.413	−0.309	1.064	−5.589	0.542
EDP	−0.167	0.447	0.304	0.012	0.141	0.407	9.712	0.830
EDS	−0.095	0.239	0.045	0.151	−0.421	1.134	17.809*	1.441
DRATIO	−0.299*	1.307	0.937	0.504	−0.006	0.027	3.552	0.465
CULTMETH	0.744***	2.019	0.461*	1.561	−0.153	0.317	37.123***	2.119
FAMILYSZ	0.221***	4.303	0.080***	2.064	0.067	0.715	1.696	0.533
ANCR	0.050***	5.559	0.027***	3 252	0.101***	2.931	0.479	0.708
SETFMYRS	0.389***	2.359	0.005	0.397	...	...	...	...
AHAT[c]	...	...	...	...	−0.186	0.506	−4.501	0.358
MZHAT[c]	...	...	...	...	−0.136	0.296	−5.196	0.396
CDD	−0.055***	3.054	−0.255**	1.791	−0.047**	1.860	0.421	0.413
LOFFEMP	−0.022	0.856	−0.034**	1.698	...	...	...	...
COOPMEM	0.826***	2.153	0.749***	2.633	1.149**	2.151	14.651	0.858
ADVICE	−0.337	1.003	−0.216	0.851	−0.053	0.157	4.521	0.417
SDUM	1.031***	3.146	0.050	0.198	−0.731*	1.550	−8.176	0.481
Z_2	1.280***	2.844	0.409	1.127	0.813*	1.319	−15.718	0.806
Z_4	0.855**	1.746	−0.316	0.774	−0 957**	1.778	−55.547***	2.507
λ^d	...	...	...	...	...	...	33.798**	1.777
$\bar{R}^2$	0.391	...	...	...	...	...	0.110	.
χ^2	...	...	76.655	...	111.150	...	...	...
N	199	...	199	...	199	...	133	..

Notes: The variables are defined in Table 19, with the exception of SETFMYRS, which is the number of years the family has resided at its present location, and LOFFEMP, which is the hours of off-farm work per household. The estimation results reported in Table 10 are for fertilizer-using households. Here the estimations are based on all 199 plateau households.

[a]Estimated by ordinary least squares.

[b]Estimated by a probit maximum likelihood procedure.

[c]Predicted values of AREAHA and USEHYM.

[d]λ is the inverse of Mill's ratio obtained from the USEFERT equation.

*Significant at the 20 percent level.

**Significant at the 10 percent level.

***Significant at the 5 percent level

more knowledge. The significance of λ in the intensity equation indicates that important differences exist between users and nonusers of fertilizers and that these differences need to be taken into consideration in estimating the intensity equation.

Effects of Crop Management Practices

Crop management practices, like choice of crops, timeliness of operations, efficient weeding, and residual fertilizers, affect the response of crops to fertilizer application. These variables, therefore, affect the quantity of fertilizer used by farmers, assuming they know the nature of these interactions. The effects of these factors cannot be captured by the household analysis because these data are plot-specific, whereas in Table 20 the average rate is derived from the sum of all plots belonging to the household. The results of a plot-specific tobit regression that seeks to explain the variation in fertilizer application rates (NPKFHA) using plot-level data from farms in the plateau are presented in Table 21. Only maize plots are considered. In addition to the variables included in Table 21, the following plot-specific variables are also considered.

PGHY	= Previous crop on the plot (hybrid maize or groundnuts = 1; others = 0),[24]
DPLANTIM	= Date of planting (weeks),[25]
NWEED	= Number of weedings done on the plot,
DISTHOUS	= Distance of the plot from the house (kilometers),
HYV	= Maize variety grown (hybrid maize = 1; local = 0), and
PM	= Cropping practice followed (sole cropping = 1; mixed = 0).

Moreover, NPKFHA is now defined as the quantity of fertilizer (kilograms/hectare) used on the plot. The results need to be carefully interpreted because of the partial nature of the model.

Among the personal attribute variables, in addition to age, the knowledge variables emerge as significant determinants of actual rates of fertilizer application. Schooling is important, and a higher level of schooling affects rates positively. The extension variable also has a significant and positive coefficient. Decisions regarding rates of application demand more knowledge. As mentioned in Chapter 4, the amount of fertilizer applied needs to be adjusted depending on specific soil, agronomic, and management situations. The results here support this. Farmers with a better knowledge base use larger quantities of fertilizer. This result also implies that the extension service has been effective in overcoming the farmers' tendency to use low rates of fertilizer application.

As expected, use of fertilizer-responsive hybrid maize results in a sharp increase in the fertilizer application rate. Delayed planting affects rates adversely. Better-weeded plots receive more fertilizer. These results imply that farmers are aware of some of the critical interactions and adjust their fertilizer application rates accordingly. Distant plots, which are more difficult to supervise, are fertilized at lower levels. These plots could also be more recently cleared fields with relatively high native fertility, thus requiring less nutrient replenishment. The nature of the cropping (sole or mixed) does not make any difference in the rate of fertilizer application.[26] This finding has implications for maize researchers. It was stated in Chapter 4 that, despite the widespread prevalence of mixed cropping, little research has been done

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[24]These crops leave residual nutrients that are available to the succeeding crop.

[25]For each location, the week of first planting was given the number 1. Actual date of planting for each plot was scaled in relation to this date. Thus, this variable measures the extent of delay in planting and is standardized over branches (locations) even though the actual dates of first planting are different across locations.

[26]Rates of application on mixed crops have been found to be lower in a number of agronomic experiments.

Table 21—Plot-level (tobit) analysis of determinants of fertilizer application rates

Variable	Coefficient	t-Statistic
Constant	102.346***	3.523
AGE	−0.924***	2.417
HEADHH	−0.488	0.039
EDP	25.315**	1.926
EDS	24.162**	1 830
DRATIO	9.985	1.178
FAMILYSZ	−4.185***	2.181
AREAHA	6.178***	2.979
ANCR	−0.030	0.329
CDD	−0.308	0.505
COOPMEM	1.177	0.090
ADVICE	20.517**	1.817
SDUM	−37.076***	3.026
CULTMETH	−8 478	0 703
PGHY	26.541***	2 445
DPLANTIM	−11 724***	4.912
NWEED	16 341*	1 544
DISTHOUS	−2.785*	1 402
HYV	95 644***	7.720
PM	−5 563	0.493
χ^2	209 000	. .
N	431	

Notes: The variables are defined in Table 19, except for the following: PGHY is previous crop on plot (hybrid maize or groundnuts = 1; others = 0), DPLANTIM is date of planting (weeks); NWEED is the number of weedings done on the plot; DISTHOUS is the distance of the plot from the house (kilometers); HYV is the maize variety grown (hybrid maize = 1; local = 0), and PM is the cropping practice followed (sole cropping = 1; mixed = 0).
*Significant at the 20 percent level.
**Significant at the 10 percent level.
***Significant at the 5 percent level.

on fertilizer use in this situation. It seems, however, that based on their practices, farmers don't consider mixed cropping an inferior response.

Some unexpected results are also obtained. The previous crop variable (PGHY) had a positive and significant coefficient. It was hypothesized that these crops (hybrid maize and groundnuts) leave some residual nutrients in the soil and, in response, farmers should use less fertilizer on the succeeding crop grown on the same plot of land. Table 21 indicates that such plots received more fertilizer in the plots surveyed here. These crops (hybrid maize and groundnuts) are extremely important from a market point of view, and plots on which they are grown obviously receive more attention. These plots may also have been cultivated for a longer period of time; therefore, farmers may be consciously trying to maintain soil fertility by using more fertilizer. This is an important hypothesis, since population pressure will continue to erode the traditional fertility-maintenance practice of fallowing. Fertilizers must assume greater significance in the future. If this result does indeed reflect this phenomenon, it provides an indication of how farmers are responding to intensification pressures. Even though the region is characterized as land-abundant, fertility and intensification-related issues are relevant in plot-specific circumstances. This hypothesis has a bearing on the sustainability versus mining arguments often put forward in literature pertaining to intensification of forest-fallow and bush-fallow systems.

In contrast to the result in Table 20, cultivation of the plot with the help of oxen did not lead to higher rates of application. This could be due to explicit inclusion of the farm size variable (AREAHA), which was highly significant and positive. This could also have affected the family size variable, which emerges as a significant negative factor. The relationships between cultivated area, method of cultivation, and labor are complex, and Table 21, which is based on a single-equation framework, obviously fails to account for these.

These analyses reveal that among the personal attributes, only old age constrains the decision to *use* fertilizers. Factors like education, gender, or extension contact and farmer's resource endowments of land, labor, and oxen do not affect this decision significantly. Agroecological differences within the plateau region are important, as illustrated by the Western Zone. This is a challenge for agricultural research. Other variables that matter in this regard are access to funds (ANCR and COOPMEM), availability of supplies (SDUM), and access to market (CDD).

These findings must be put in proper perspective. Farmers in the study area have been experimenting with fertilizers for a long time. A favorable incentive environment has encouraged this process. Knowledge regarding fertilizers is well diffused and is accessible to all categories of farmers. Many of the sociocultural and economic factors usually associated with adoption of innovations are no longer relevant. The only constraints are those of liquidity, in order to buy fertilizers, and accessibility to markets and supplies. However, over a large part of Africa (indeed, even within Eastern Province in the valley and the Western Zone of the plateau), most of these favorable conditions do not obtain. In these situations, factors such as research, extension, and education may assume greater significance.

The roles of education and extension are clearly revealed in analyses pertaining to decisions on rates of fertilizer application. These depend on specific agronomic and management conditions, which vary from plot to plot. Farmers need more knowledge to efficiently respond to these situations. Thus, knowledge-related variables assume greater significance. The analyses indicate that farmers, in fact, do adjust their rates of application in response to factors such as planting time, variety, and weeding. These results imply that in the plateau region, the extension services should concentrate more on educating farmers about fine-tuning their fertilizer use practices to further improve the efficiency of fertilizer use. Farmers in the plateau region are generally well beyond the initial phase, where convincing them to use fertilizers is the prime extension task.

In terms of the role of state policy and public investments, strong results were obtained. Education, credit, infrastructure, and fertilizer distribution all affect decisions regarding fertilizer, but current levels of these investments are low (NCDP 1989). Extension plays an important role in improving fertilizer use efficiency. In Eastern Province, extension and research that feeds into the extension system have received some support in recent years through a World Bank-supported agricultural development project. Underlying all of these results has been the government support of maize prices and marketing policy. Without these—and, of course, the favorable fertilizer response environment—fertilizer use would not have taken off in the province. Focusing exclusively on household-level regressions would completely bypass these important preconditions.

To summarize, both area expansion and yield improvements appear to be occurring simultaneously over most of the plateau region. This supports the view that even in land-surplus regions, yield-increasing inputs can play an important role (Binswanger and Pingali 1988; Lele and Stone 1989). There are two key provisos, however. First, a high natural potential for the use of such technologies must exist, and second, committed support for marketing and infrastructure and remunerative prices must prevail. In the initial phases, there is no substitute for the role of the state in providing these and other services such as extension, veterinary services, credit, and even input distribution.

8

FERTILIZER USE AND TRANSITION TO COMMERCIAL AGRICULTURE

It was hypothesized in Chapter 2 that the process of transformation from subsistence to commercial agriculture in the plateau region is triggered by the use of fertilizer on local maize. The resulting surplus is then used to cultivate more land and put more area under a purely commercial hybrid maize crop. Since plenty of arable land is available and animal traction is feasible, the process culminates in larger holdings and substantial commercial production. This perception of the transition process is reinforced by (1) the fertilizer allocation behavior of the sample households—some farmers were using fertilizers for local maize, some for both local and hybrid maize, and some for hybrid maize alone (Table 9), and (2) the increase in the importance of hybrid maize with farm size (Table 14).

Analyzing these distinct patterns of fertilizer allocation behavior should provide insight into the process of transition. By classifying farmers in categories according to this criterion (fertilizer use) and trying to understand the factors responsible for differences between the groups, it should be possible to identify some elements of this dynamic transition process. It should be noted, however, that fertilizers are only a part of this process; therefore, the perspective derived from this analysis is partial.

The transition process is analyzed with the help of an ordered probit model, which attempts to explain a household's progressive movement from no fertilizer use to fertilizer use on hybrid maize only, representing the progression from subsistence to commercial agriculture. The dependent variable is defined in an ordered form as follows:

Category	Number of Households
No fertilizer use = 0	68
Fertilizer use on local maize only = 1	64
Fertilizer use on local and hybrid maize = 2	57
Fertilizer use on hybrid maize only = 3	10

The set of independent variables includes personal (farmer-related) and resource endowment characteristics. Institutional and agroecological factors are also considered. Variables like cultivated area, adoption of hybrid maize, oxen, and farmers income and liquidity are all part of the transition phenomenon being explained and are not included as explanatory factors.

Data on mean levels of the relevant variables in each of the four categories are presented in Table 22, and results of the ordered probit regression are provided in Table 23. A trend can be discerned from some of the variables in Table 22. For example, all indicators of transition—cash income, cash sales, cultivated area, and

Table 22—Mean values of variables in each fertilizer user category

Variable	Fertilizer Use			
	None (0)	Local Maize Only (1)	Local and Hybrid Maize (2)	Hybrid Maize Only (3)
CASH INCOME/CAPITA	40.35	133.47	305.89	157.49
ANCR	2.43	6.64	19.54	12.91
USEHYM	0.01	0.06	1.00	1.00
AREAHA	1.84	1.66	4.21	6.36
CULTMETH	0.53	0.53	0.86	0.90
AGE	46.91	42.15	39.98	44.00
HEADHH	0.43	0.33	0.21	0.20
EDP	0.20	0.25	0.28	0.30
EDS	0.23	0.31	0.47	0.20
DRATIO	0.72	0.66	0.81	0.70
FAMILYSZ	6.04	4.98	6.39	8.20
COOPMEM	0.07	0.19	0.26	0.60
ADVICE	0.20	0.34	0.30	0.10
CDD	19.60	13.92	13.63	10.47
Number of observations	68	64	57	10

Notes: The variables are defined in Table 19, with the exception of CASH INCOME/CAPITA, which is defined as total cash sales from all sources in kwacha.

Table 23—Results of an ordered probit regression explaining transition to commercial agriculture

Variable	Four Categories (0, 1, 2, 3)	
	Coefficient	t-Statistic
Constant	1.721***	3.116
AGE	−0.019***	2.561
HEADHH	−0.397**	1.734
EDP	0.149	0.649
EDS	−0.180	0.714
DRATIO	0.004	0.022
FAMILYSZ	0.078***	2.718
COOPMEM	0.684***	2.946
ADVICE	−0.158	0.680
CDD	−0.038***	3.358
SDUM	−0.465***	2.000
Z_2	0.308	1.091
Z_4	−0.636**	1.877
χ^2	76.727	. .
N	199	. . .

Note: Variables are defined in Table 19.
*Significant at the 20 percent level
**Significant at the 10 percent level.
***Significant at the 5 percent level.

use of hybrid maize—rise with ascending categories. This corroborates the proposed conceptual framework: the categories do seem to reflect a transition pathway. The proportion of female-headed households declines, whereas the share of households with primary schooling, use of oxen, and membership in a cooperative increases as agriculture becomes more commercialized, as expected. The income indicators of the most progressive group (category 3) are lower than the trend, but other variables generally conform to expectations. The regressions reported in Table 23 identify the main forces more clearly.

Older farmers and households headed by females find it difficult to ascend the commercialization hierarchy. Although neither fertilizer adoption nor intensity of use is influenced by gender, as shown in Chapter 7, women farmers are more likely to fertilize local maize only (Table 10). And women farmers find it difficult to graduate to higher levels of fertilizer use (Table 23), possibly because they are reluctant to grow hybrid maize (Table 20). It has been argued that poor processing and storage qualities make hybrids less preferable for domestic consumption (Jha, Hojjati, and Vosti 1991; Kydd 1989), and female-headed households place greater emphasis on family food production than on sales. Women farmers may also be at a disadvantage in other respects. Since households headed by women are generally short of adult labor, particularly male labor, women farmers may not have time to be involved in cash transactions that require travel, interactions with institutions primarily oriented toward dealing with men, and time-consuming cash generating and purchasing activities. In Eastern Province, cash transactions are primarily associated with men; farming and household chores are the domain of women.

Education does not emerge as a significant determinant of fertilizer use. This may be due to the partial nature of the model, which focuses only on fertilizers. A large family, which denotes higher consumption needs and a better labor supply, exerts a strong positive influence. Better infrastructure and availability of credit also play important contributory roles. Obviously, inefficiencies in input distribution dampen the process of commercialization.

The effects of another significant state intervention—animal disease control—should be mentioned. The entire province is vulnerable to tsetse infestation, and constant vigilance has to be maintained to contain incidence of the disease in the plateau region. The valley cannot sustain any cattle population because of the disease. Government-sponsored animal disease control measures such as quarantine, sprays, dips, and veterinary clinics have contributed to greater use of animal traction in the farming system. Despite such efforts, cattle rearing remains risky, particularly in the Western Zone. In Petauke and Nyimba districts, which account for most of the Western Zone area, for example, the cattle population declined by 37 percent between 1982 and 1984 because of cattle mortality (Eastern Province, Department of Agriculture 1986a). Although the data from the survey do not show lower levels of oxen use in the Western Zone (Table 2), higher risk levels could adversely affect cash input use (for example, for fertilizer). These relationships need to be explored in future studies.

Three significant inferences arise from these results. First, the prospects for progress for women farmers are constrained. Because nearly a third of the smallholder farms in the study area are headed by women, this issue clearly requires more attention in research and in public programs. Second, factors external to the farming system are crucial. Credit, infrastructure, input distribution, animal disease eradication, and of course, marketing, play decisive roles in the transition process. Many of these are outside the normal jurisdiction of the Ministry of Agriculture. A strategy for agricultural transformation that ignores these investments, however, is unlikely to go far. Finally, agroecological characteristics play a significant role. It is important to identify these system constraints.

This pattern also lends credibility to the concept of the "*lima* ladder" put forth by Zambian researchers (see Chapter 2 and Appendix 1). The initial step is to get subsistence farmers to produce a small area of a cash crop—soybeans or sunflowers, and to use the proceeds to buy fertilizers. In the next step (season), this fertilizer is applied to local maize. One argument proposes that the farmer who uses fertilizer can plant a smaller area in local maize because, with fertilizer, he can produce enough on a smaller area for subsistence. He can use the labor, thus released, to grow hybrid maize. Subsequently, sales of hybrid maize would give him enough cash to hire more labor or oxen to increase the area under hybrid maize further. The actual progression appears to be similar, only the initial cash crop component seems to be weak. Very few of the sample households grow soybeans, sunflowers, or cotton, perhaps because the seed supply and marketing arrangements for these new crops are weak. At least some farmers manage to skip this step and somehow (perhaps with credit) arrange to acquire fertilizer, which is put on local maize. Subsequent steps of increased hybrid maize production and expansion of cultivated area follow.

The plateau region of Eastern Province illustrates how policy-led intensification works (Lele, Christiansen, and Kadiresan 1989; Binswanger and Pingali 1988). By assuring that prices are remunerative and backing them up with effective procurement, the state has induced intensification in a land-surplus environment. Use of yield-increasing inputs (hybrid seeds and fertilizers), as well as area expansion, are proceeding side by side. This is probably not happening in the valley region because of a number of constraints—both agroclimatic (uncertain responses and prevalence of tsetse) and infrastructural (lack of adequate roads and services). The lesson is to target investments and interventions only after a careful analysis of farming system characteristics. Animal disease control is a critical step in this process.

Some important conclusions have emerged from the analyses in the last two chapters. First, among the personal attributes, age has the greatest negative influence on fertilizer use. And, although much concern has been voiced on the constraints faced by women farmers, this analysis does not show them to be lagging behind in fertilizer use, though other factors such as their reluctance to grow hybrids do inhibit their progression toward increased commercialization. Education has a positive effect in more sophisticated fertilizer use decisions (application rates, for example). In an area where farmers have long been exposed to fertilizers, extension advice does not seem to influence the decision to use fertilizers, but there is some indication that extension efforts have an effect on decisions that require more technical knowledge, such as rates of application. Farmers also seem to be aware of the need to adjust fertilizer use levels in response to deviations from optimal crop management practices. Extension has obviously contributed to the improved technical efficiency of fertilizer use by communicating these messages to farmers.

Among the institutional factors, access to credit, infrastructure, and input distribution are found to be most important, and most of these determinants are in the public domain. Credit, infrastructure, extension, and education are all provided by the state. In Zambia, fertilizer distribution is also a state activity. State support has also enabled animal disease eradication measures and the resulting growth in use of animal traction. Clearly, more public investment in the rural sector is crucial for promoting further growth in fertilizer use and output in the Eastern Province.

The state also plays a vital role in pricing and marketing areas. Through most of the 1980s, it was successful in maintaining a favorable incentive environment. In the current context of higher fertilizer prices and pressures to minimize the role of the state, some of these critical functions and roles need to be provided for.

9

CONCLUSIONS AND POLICY IMPLICATIONS

Results presented in the preceding chapters establish quite clearly that the plateau region of Eastern Province is an area with high potential for fertilizer use, and the process of diffusion of fertilizer use is well on its way. The other region, the valley, faces agroecological and infrastructural constraints that inhibit fertilizer use. Over two-thirds of the sample households in the plateau region were fertilizer users in 1985/86, and more than half the cultivated area was fertilized. At 53 kilograms of total plant nutrients per hectare of cultivated land, the rate of application in this region is way ahead of that in the country as a whole, which averages about 20 kilograms. Fertilizer use, which started in the late 1960s, has grown rapidly in Eastern Province ever since. A high physical response environment, favorable relative prices, and the ability to procure farmers' surpluses have all contributed to this development. The experience in the plateau region demonstrates that even in a highly land-surplus situation, yield-increasing inputs are a viable option, if the above conditions are met. The process has been accompanied and probably fueled by concomitant growth in cultivated area (due to use of animal traction) and growth in area under highly fertilizer-responsive hybrid maize.

These trends highlight two important policy issues. First, the gap between the plateau and the valley strengthens the argument for regional targeting of scarce fertilizers to areas of high use potential. Without significant new investments in agricultural research, infrastructure, and the marketing and distribution network, fertilizer promotion efforts in the valley would be fruitless. Second, the importance of incentives and market infrastructure in promoting fertilizer use should be stressed. Farmers have responded to these opportunities, when available, and have achieved significant gains in surpluses and incomes. More will be said on this later.

A significant finding of this study is the total domination of the fertilizer scene by one crop, maize. Fertilizer use has diffused to varieties other than hybrids, but it is still almost exclusively based on one crop. This has important implications for future growth in fertilizer use and output. Since the gap between recommended and actual levels of fertilizer application on maize is not very large, that leaves three major sources of future growth in fertilizer use: increase in fertilized local maize area, increase in hybrid maize area, and absolute increase in cultivated area itself. Availability of surplus land ensures that if the economic environment remains favorable, these growth sources will remain important. Changes in relative fertilizer prices beginning in 1989/90 threaten growth in fertilizer use and output of maize. Thus, from the longer-term point of view, diversification of fertilizer use to other crops is crucial. Cotton and carioca beans have been highly responsive to fertilizer, and use on these crops needs to be encouraged. Research on other crops and regions also needs to be strengthened. In particular, adequate attention should be paid to relative fertilizer-output prices.

The evidence obtained in this study on the roles of education, credit, input distribution, and infrastructure in promoting fertilizer use and transformation of subsistence agriculture is strong. All these fall in the public domain, as does maize marketing. The state has also played a role in expansion of animal traction in the plateau through animal disease control. These social, institutional, and physical infrastructure investments are extremely important and should be accorded high priority.

Agricultural extension is another area of public intervention that has been accorded high priority in recent years. Substantial efforts have been made to reorganize the provincial extension system along the lines of the training and visit system supported by the World Bank. Perhaps because fertilizer use is already well diffused in the plateau region, the cross-sectional analysis failed to capture any effect of extension on adoption. However, there was evidence that decisions on rates of application were influenced by extension advice. As the experimental evidence shows, response to fertilizer is significantly influenced by other crop management practices such as time of planting, weeding, and residual fertilizer effects. The analysis here shows that farmers were aware of some of these interactions and adjusted their fertilizer use practices accordingly. This also indicates that the extension services were able to convey these messages. What is needed now is more site- and system-specific advice on fertilizer use. The focus in extension should shift from promoting fertilizers to fine-tuning fertilizer use practices, at least in the plateau region and for crops other than maize. In other areas (like the valley) where fertilizer experience is deficient, the on-farm experimentation and demonstration roles of extension could be important. Older farmers and women who operate farms continue to be somewhat rigid in their responses to innovations. Over time and with education this will change, but in the short term these groups should receive special attention in extension programs.

Turning to the issue of agricultural research, the capacity to conduct on-farm research is severely constrained. There is practically no capacity at the Masumba substation in the valley region. The current needs of farmers include location-specific recommendations and information on fine-tuning of fertilizer use practices, nutrient balance, efficient forms of fertilizer, and use of fertilizer on crops other than maize, all of which require more on-station and on-farm research. Prices of different fertilizer mixtures, for example, should reflect the cost of their nutrient content. Even within the plateau, the Western Zone had low fertilizer use indicators, which should be investigated in depth.

Analysis of the patterns of fertilizer allocation decisions by farmers has provided useful insights into the process of transformation going on in the plateau region of the province. The transition from subsistence to commercial agriculture was triggered by the use of fertilizer on local maize. The resulting surplus fueled expansion of area and hybrid maize production. Availability of surplus land and oxen facilitated the process. To abet this process, the crucial first step of finding cash to buy fertilizers could be aided by credit, or, as proposed under the *lima* ladder concept, by enabling farmers to grow small areas of cash crops. Both concepts require strong support. Education, credit, infrastructure, and input supplies, and potential for oxen use are identified as some of the facilitating forces behind the transition process. It is useful to bear in mind, however, that this recipe depends on a set of initial conditions—a high physical response environment, abundant land and the means to cultivate it, and a favorable incentive structure. In this setting, yield-increasing technologies go hand-in-hand with area expansion.

Finally, a word about women farmers who constitute about one-third of the farming community. This analysis clearly shows that they do not lag behind in terms of adoption of fertilizers. However, their ability to move up to higher levels of commercialization is constrained by their reluctance to grow hybrid maize. Policies to overcome this reluctance need to be found.

Growth in fertilizer use in Eastern Province has some useful lessons for areas with similar farming systems in Zambia and other parts of central and southern Africa. A number of factors contribute to the diffusion of fertilizers and greater commercialization of the farming sector, and these imply investments. The following play important roles:

- favorable price and physical response environments;
- investments in market and transport infrastructure and animal disease control;
- agricultural research to enhance fertilizer use potential;
- investments in education, extension, and credit; and
- development of economic institutions for surplus mobilization and input delivery systems.

These suggest several actions that are important in policy design. However, the results of the study are limited inasmuch as the recommendations cannot be prioritized. A policy of intervention to improve the efficiency of public expenditures is a major concern of the Zambian government's structural adjustment program. In setting priorities, the government also must take into account the expenditure requirements of different actions.

APPENDIX 1: LIMA LADDER FOR EASTERN PROVINCE HOE CULTIVATORS

Mount Makulu National Research Station suggested the name "*lima* ladder" for a practical series of steps a smallholder can take to improve his position from that of a subsistence cultivator barely growing enough maize for his family to a hybrid maize grower with a good cash income, and without waiting for credit that may never come (see Figure 4).

The plan is to grow more late season crops like soybeans or sunflowers or beans to raise cash to buy fertilizer for local maize, then to grow less area of local maize (but with fertilizer) so that the yield is greater than before, which enables the farmer to have more time (previously given to a large local maize area) to grow more cash crops to sell or to grow hybrid maize.

Figure 4 —*Lima* ladder

Oxen (larger area)

↑

Season 4

Farmer hires oxen; grows 4 *limas* of hybrid maize

↑

Season 3

Farmer halves local maize area, adds 2 *limas* of hybrid maize (fertilizer or cash from surplus maize, and sunflower or soybean crop sold)

↑

Season 2

Farmer sells (or barters) 4 bags of sunflower seeds for 4 bags of fertilizer for his local maize (or buys fertilizer with cash from 2 bags of soybeans)

↑

Season 1

Farmer grows 1 *lima* of soybeans or 1-2 *limas* of sunflowers (the farmer is more likely to have labor for this in late December/early January rather than trying to grow more groundnuts to sell, which need labor when the farmer is busy planting and weeding local maize)

↑

Last Season

Subsistence farmer with no cash crop and no fertilizer for his local maize

Source: Based on Eastern Province, Department of Agriculture, "Plateau Camps with Cotton," Bulletin No. 2, Chipata, Zambia, December 1986

Note: A *lima* is a small plot of land (0.25 hectare).

APPENDIX 2: SUPPLEMENTARY TABLES

Table 24—Location of sample households

Region/ Agricultural District	Branch (Location)	Number of Households	
		Branch	Sample
Eastern Plateau Region			
Chadiza	Chipili	221	33
Chipata South	Makangila	405	31
Chipata North	Mtenthela	214	33
Katete	Sinda	247	33
Lundazi	Chaweya	138	33
	Kasendeka	148	33
Nyimba	Kamwala	306	33
Petauke	Chiwizi	257	33
Luangwa Valley Region			
Chama	Nkhoka	89	33
Mambwe	Mphata	159	33
Total		2,184	328

Source: Agricultural household survey conducted in 1985/86 by the International Food Policy Research Institute; the Rural Development Studies Bureau, University of Zambia; the National Food and Nutrition Commission, Zambia; and the Eastern Province Agricultural Development Project, in Eastern Province, Zambia.
[a]A branch is a cluster of villages selected from a district in Eastern Province for the survey above.

Table 25—Marketed production of maize, groundnuts, and cotton in Eastern Province, 1978-87

Year	Marketed Production		
	Maize	Groundnuts	Cotton
	(1,000 metric tons)		
1978	69.4	1.7	2.8
1979	46.6	2 2	3.4
1980	66.6	1.4	3 7
1981	106.6	0.9	1.8
1982	114.6	0.7	1.5
1983	143.8	0.9	2 6
1984	166.7	1.0	4.8
1985	176.8	4.7	3.7
1986	224.3	6.2	2.9
1987	189.8	8.2	n.a

Source. NCDP (National Commission for Development Planning), *New Economic Recovery Program, Fourth National Development Plan: 1989-1993* (Lusaka, Zambia. Office of the President, 1989)

Table 26—Adaptive Research Planning Team (ARPT) trials, 1982/83-1987/88

Title of Trial	Period	Location of Trial
Maize/groundnut intercropping	1982/83, 1983/84	ST
Maize fertilizer	1982/83, 1983/84, 1986/87, 1987/88	F
Sunflower variety fertilizer	1982/83	F
Sorghum variety	1982/83, 1983/84	F
Sorghum/sunflower/legume intercropping	1983/84	ST
Sorghum planting method	1983/84 (failed)	ST
Shorter-duration maize hybrids	1982/83 to 1985/86	F
Maize open-pollinated variety trials	1982/83 to 1986/87, 1987/88	F
Sunflower planting, date/thinning	1983/84	F
Sunflower thinning	1984/85 to 1985/86	F
Cotton fertilizer	1983/84 to 1984/85	F
Finger millet variety test	1982/83 to 1984/85	F
Maize management factorial	1982/83 to 1985/86	ST
Maize weeding (on station)	1982/83 to 1984/85	ST
Maize weeding (on farm)	1985/86 to 1986/87	F
Maize field factor (pop/fert)	1982/83 to 1986/87, 1987/88	ST
Live mulch (Mwase CDA)	1982/83 to 1986/87, 1987/88	ST
Rice fertilizer	1982/83 to 1986/87, 1987/88	ST
Rice variety	1982/83 to 1986/87, 1987/88	ST/F
Rice planting method	1983/84 to 1985/86	ST
Sorghum/maize/soya intercropping	1984/85 (failed)	ST
Bean exploratory (nonclimbing)	1983/84 to 1986/87, 1987/88	F
Bean exploratory (climbing)	1985/86 to 1986/87, 1987/88	F
Residual N/rotation	1983/84 to 1986/87	ST
Striga control	1984/85 to 1986/87	ST
Striga suppression	1985/86 to 1986/87	ST
Soybean fertilizer	1984/85 to 1986/87	F
Finger millet variety trial	1985/86 to 1986/87, 1987/88	ST/F
Relay cropping trial	1986/87, 1987/88	F/ST
Cotton/groundnut intercropping	1986/87, 1987/88	ST
Finger millet management	1986/87, 1987/88	ST
Soya seed rate	1986/87	ST
Pigeon pea variety	1986/87, 1987/88	F
Groundnut factorial (with CRT)	1986/87, 1987/88	F
Soil conservation (obser. trials)	1986/87, 1987/88	F
Sweet potato variety trial	1987/88	ST
Cowpea variety trial	1987/88	F
Alternative late season crops trial	1987/88	F/ST

Source. EPADP (Eastern Province Agricultural Development Project), "Eastern Province Agricultural Development Project: Project Completion Report" (Chipata, Zambia, November 1987, mimeographed).
[a]F indicates on-farm and ST on-station trials.

Table 27—Fertilizer and maize prices in Zambia, 1980/81 to 1989/90

Year	Price of Urea	Price of 10-20-10 Compound	Average Nutrient Price[a]	Maize Price
		(kwacha/kilogram)		
1980/81	0.19	0.19	0.45	0.13
1981/82	0.22	0.23	0.53	0.15
1982/83	0.30	0.30	0.70	0.18
1983/84	0 48	0.48	1.12	0.20
1984/85	0.52	0.52	1 18	0.27
1985/86	0.54	0.53	1.25	0.61
1986/87	1.30	1.60	3.42	0.87
1987/88	1.30	1.60	3.41	0.89
1988/89	1.42	1.97	4.41	1.39
1989/90	7.68	7.92	18.25	3.16

Source: Fertilizer prices from FAO (Food and Agriculture Organization of the United Nations), *FAO Fertilizer Yearbook* (Rome· FAO, various years). Maize prices from L. Mumeka, "Policy Constraints on the Development of Agriculture and Small-Scale Enterprises in Rural Zambia," in *Adopting Improved Farm Technology: A Study of Smallholder Farmers in Eastern Province, Zambia,* ed. R. Celis, J. T. Milimo and S. Wanmali, 62-92 (Washington, D C.· International Food Policy Research Institute, 1991).

[a]Derived as the average of the nitrogen price of urea (46N) and the price of a kilogram of nutrient mix of 10-20-10 compound. These are the two major fertilizers used in Eastern Province, and they are applied equally.

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