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MACRO TRENDS AND DETERMINANTS OF FERTILIZER USE IN SUB-SAHARAN AFRICA

by

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EXECUTIVE SUMMARY

Objectives: To reverse the declining trends in soil fertility levels in Sub-Saharan Africa (SSA), the use of fertilizers and other land augmenting technologies needs to increase. While overall fertilizer consumption in SSA has increased by as much as 200% from 1970 levels, the growth has been highly variable across countries, regions and time. Fertilizer use is significantly lower than that observed in other parts of the developing world, especially Asia, where fertilizer (along with other productivity enhancing technologies) has been credited with the large increases in yields. Moreover data for the 1990s suggests that overall fertilizer consumption in SSA has been declining.

Designing appropriate policies and interventions to stimulate fertilizer demand and supply, calls for a good understanding of past trends and factors that have been associated with changes in use. In this paper our objective is to seek a better understanding of the dynamics of fertilizer use, specifically with regards to:

- the trends in fertilizer consumption at the continental, regional and country level.
- the factors associated with changes in fertilizer use.

Findings:

On trends in fertilizer use

- Aggregate figures for fertilizer consumption in SSA show a steady increase, measured in terms of both absolute levels (metric tons of fertilizer consumed) and dosage (kilograms per hectare of arable land).
  - Consumption of fertilizer in 1970 was 425 million metric tons and has increased at a rate of almost 36 thousand MT per year.
  - Fertilizer dosage (per cultivated area) rose from 3.3 kg/ha in 1970 to 9.9 kg/ha in 1995.

- Notwithstanding the above figures, fertilizer use has been highly variable and concentrated among a few countries.
  - For the period 1991-1995, consumption varied from a low of 1.95 thousand MT for the Central African Region to a high of 16.55 thousand MT for Southern Africa.
  - For the same period, the four countries (Ethiopia, Kenya, Nigeria, and Zimbabwe) used 60% of all fertilizer in SSA, with Nigeria having accounted for the largest share.

On key determinants affecting fertilizer use

- The correlation analysis conducted in this paper found that fertilizer use per hectare was positively correlated with:
  - the amount of rainfall per year. This finding underscores the need to find seed/fertilizer technologies that are more responsive in the type of low moisture situation that characterizes much of SSA.

- the density of road infrastructure. However the size and significance of the road density co-efficient has been declining over time, especially since the early 1980s.
- the number of children in school (both primary and secondary). This suggests that investments in schooling may have indirect effects on stimulating fertilizer use (e.g., by improving human capital at the farm level and among those providing services to farmers).
- the percentage of cultivated area devoted to cotton. Cotton production schemes have been used to introduce fertilizer to small farmers in a variety of SSA settings where the use has subsequently been expanded to other crops, particularly coarse grains. The lesson to be learned from this variable is not so much that cotton *per se* is the best way of getting fertilizer into the farming system, but that some type of cash crop scheme that provides farmers with reliable input, credit, extension, and output marketing services can play a significant role in promoting fertilizer adoption.

- A number of factors that we expected to be highly correlated with fertilizer use per hectare did not exhibit statistically significant coefficients in the broad analysis using data from more than 30 countries. Among the most surprising were:
  - Share of area cultivated in maize. This result is surprising as maize is generally considered the most significant user of fertilizer in SSA (accounting for about 25% of total use), and it is a crop that Desai and Gandhi (1988) found to be highly correlated with fertilizer use between 1979 and 1983. We believe the link between fertilizer use and maize production warrants careful monitoring in the future because maize is one of the most fertilizer responsive crops grown in SSA and it has been the crop of choice for introducing fertilizer to farmers in a number of recent extension efforts (e.g., the Sasakawa/Global 2000 programs).
  - Share of cultivated area benefitting from irrigation. The lack of correlation between fertilizer use and percent of area irrigated is also a bit of an anomaly as the irrigated production schemes we are familiar with in SSA (e.g., Mali's Office du Niger and the Senegal River Basin) use large quantities of fertilizer per hectare. It is possible that the total amount of irrigated area in SSA is so small that it is not possible to show a statistically significant relationship with the aggregated data covering so many diverse countries.

Although our analyses provide some important insights into recent fertilizer use trends and determinants at an aggregated level, there are still many unknowns. A critical first step in developing a better understanding of factors that are driving fertilizer use at both the country and the regional level is improving the fertilizer data base in each country. Among the key improvements needed are better dis-aggregations by agroecological zone, crop, and type of fertilizer used. Data series on fertilizer prices by location and type of fertilizer would also be helpful. When these types of data become available at the country-level, both national and regional policy analysis will improve.

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1. INTRODUCTION

For Sub-Saharan Africa (SSA) to successfully satisfy the growing demand for food in both rural and urban areas, agricultural productivity must increase. Historically gains in agricultural production in SSA have come through expansion of area cultivated. However, population pressures have all but exhausted the supply of productive land in many countries. Farmers are now forced to reduce the length of fertility-restoring fallows and expand onto environmentally fragile lands. It is estimated that by 2010, SSA fallows will have disappeared in 20 countries and will constitute less than 25% of arable lands in another 29 countries (Angé 1993). By some accounts 72% of African arable land has already been degraded as a result of soil erosion (Oldeman et al. 1991). Increased cultivation on less productive lands is a major cause of declining yields in many parts of SSA.

To reverse the declining trends, intensification through the use of fertilizers and other land-augmenting technologies is essential. Experience has shown that chemical fertilizers, the subject of this paper, are one of the most powerful productivity-enhancing inputs available. A third of the increase in cereal production world-wide and as much as half of the increase in India's grain production has been attributed to fertilizer-related factors. Data on agricultural potential for six continents rank Africa second (after Latin America) in terms of the theoretical maximum levels of attainable production, yet without increased use of improved inputs, such as fertilizers, SSA is unlikely to realize this potential.

In recent years there has been growing concern about declining soil fertility and new initiatives to address the problem[1]. Developing sound policies and programs to improve SSA soil fertility calls for a good understanding of past trends and factors that have been driving them. This paper contributes to the need for a better understanding of these issues by addressing key questions:

- What fertilizer consumption trends are at the continental, regional and country level?
- How do trends in SSA compare with those in other parts of the world?
- What factors are associated with higher fertilizer use?

The objective of this paper is to examine the extent to which these questions can be answered using country-level data available in published FAO (1988) and World Bank sources. This paper is the second in a series of three documents that examine the determinants of fertilizer use in SSA. The first document reviews the current state of knowledge concerning farm-level profitability and incentives to use fertilizer relying primarily on fertilizer trials, farm surveys and policy literature (Yanggen et al. 1998). The third document examines literature on fertilizer adoption (Reardon et al. forthcoming).

[1] The World Bank, FAO, ICRAF, IFDC, IFA, IFPRI, and USAID, among others, issued strong statements at the World Food Summit concerning their support of soil fertility activities in SSA. The Netherlands, Norway, Belgium, the Club du Sahel and the Global Environment Facility have provided funding for the World Bank-sponsored Soil Fertility Initiative (SFI) aimed at assisting African governments develop and implement soil fertility management plans.

In Section 2 of this document we describe the trends in SSA fertilizer consumption and compare them to other regions. Section 3 presents the conceptual framework we used for identifying factors that might have an impact on fertilizer consumption. Section 4 presents the empirical results concerning exogenous factors that do, and do not, have statistically significant links to fertilizer consumption. Section 5 discusses problems of estimating regional and national fertilizer demand models for SSA. Section 6 concludes with the policy and research implications of the findings.

2. TRENDS IN FERTILIZER CONSUMPTION

There are a variety of perspectives from which one can evaluate recent trends in SSA fertilizer consumption. Some perspectives provide a more positive picture of recent trends than others. For example, aggregate figures for fertilizer consumption in Sub-Saharan Africa show a steady increase, measured in terms of both absolute levels (metric tons (MT) of fertilizer consumed) and doses (kilograms per hectare of arable land). Data show that in 1970, the amount of fertilizer consumed by SSA was only 425-thousand MT. Consumption increased at a rate of almost 36-thousand MT per year, peaking at 1.45-million MT in 1993, but declining to 1.38-million MT in 1995 (Figure 1). This represents an increase of more than 200% over the 26-year period. Total cultivated area for SSA also increased, during the same period, at a rate of 820 thousand ha per year (Figure 1)[2]. Total cultivated area in SSA also increased during the same period at a rate of 820 thousand ha per year (Figure 1), but the growth in fertilizer consumption exceeded the rate of expansion of cultivated area. Fertilizer doses (per cultivated hectare) rose from 3.3 kg/ha in 1970 to 9.9 kg/ha in 1995 (Figure 2), a 200% increase.

With the above figures and accompanying graphs, one may be led to believe that the use of fertilizer in SSA is rapidly increasing and contributing to higher levels of aggregate productivity. Unfortunately, the aggregate figures presented mask three important features of fertilizer use in SSA. First, the use of fertilizer is highly variable across different regions (even within individual countries) and also across different time periods. Second, the amount of fertilizer consumed in SSA dwarfs in comparison to amounts used in other developing regions of the world. Third, while the trend line of fertilizer shows a positive growth overall, the reality is that in the most recent years there has been an actual decrease in fertilizer consumption.

Desai and Gandhi (1988), using data from 1960 to 1983, noted that the "Sub-Saharan fertilizer scene is characterized by very low levels and by extremely sharp variation" across both time and space. The "scene" has not changed much since. During the latest five-year period (1991-1995), for which data are available, the consumption of fertilizer varied from 35-thousand MT for the Central African Region to 485-thousand MT for Coastal West Africa (Table 1). Fertilizer consumption was also highly concentrated, with one or two countries in each region accounting for the majority of the consumption. Using the same five-year period, for example, Cameroon accounted for 69% of all the fertilizer consumed in the Central African Region and Nigeria accounted for 82% of fertilizer consumption in Coastal West Africa. Concentration of fertilizer use was also observed at the SSA regional level. Four countries (Ethiopia, Kenya, Nigeria and Zimbabwe) used 60% of all fertilizer in SSA, with Nigeria having accounted for the largest share.

A better measure of fertilizer use is a fertilizer dosage (kg/ha), which accounts for differences in cultivated area between countries. Even with this measure, large variations are observed. Across regions, for the period 1991-1995, fertilizer consumption ranged from 1.95 kg/ha for the Central African Region to 16.55 kg/ha for Southern Africa. At the country level consumption varied

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[2] Cultivated area here refers to land under temporary as well as permanent crops. It also includes temporary fallows. We have used FAO's "Arable land plus land under permanent crops" category as being the cultivated area.

from a low of 0.20 kg/ha for Uganda to 258.62 kg/ha for Mauritius. The variation is even more apparent when one considers that the average fertilizer consumption for this period was 20.22 kg/ha while the median was 4.67 kg/ha[3].

Like the aggregate levels of fertilizer consumption across countries in SSA, consumption growth rates vary widely. Although no single region exhibited lower fertilizer doses (kg/ha) in 1991-1995 than in 1970-1974, fourteen individual countries[4] did experience such a decline, some more dramatic than others. For example, Congo consumed an average of 44.7 kg/ha in the period 1970-1974 but only 11 kg/ha 1990-1994. Nevertheless, most countries have increased their consumption levels, with six countries increasing it more than ten-fold[5]. Many of the declines in consumption are associated with periods of civil unrest or the early period of structural adjustment programs. Many of the advances appear to be periods of recovery after such declines. A common characteristic that emerges from the examination of the data is the sharp year-to-year variation in fertilizer use. Such variation gives the trend in fertilizer use a random look. Figure 3 shows such a case for Coastal West Africa. Liberia and Ghana are extreme cases characterized by sharp year-to-year variations, while Ivory Coast, having less variation, is characterized as having more prolonged periods of growth being negated by occasional sharp drops in consumption.

It is helpful to put some of these numbers in perspective by comparing them to other developing regions. Sub-Saharan Africa consumes less fertilizer than all other regions of the world in terms of both absolute levels and doses. For the period 1991-1995 SSAs average annual consumption of 1.3-million MT amounted to a little over 1% of total global fertilizer consumption, despite the fact that it has 10% of the world's arable land. The low levels of consumption imply that doses are also low by world standards. For example the SSA average of 8.9 kg/ha for 1991-1995 stands in sharp contrast to those of Latin America (54 kg/ha), Southern Asia (80.3 kg/ha), and South East Asia (86.9 kg/ha). Growth in fertilizer consumption for SSA has also been undistinguished, especially when one considers that it consumes the least amount of fertilizer. The developing countries of Asia experienced an increase in fertilizer consumption at rates of 10.77% per annum (for South East Asia) and 22.26% (for South Asia) from 1970-1995, far higher than the 6.9% experienced by SSA and 5% by Latin America.

SSA has experienced a decline in fertilizer growth rates since 1990. Growth for 1970-1990 was 7.9%, but for the period 1991-1995 growth has slowed to 2.6% per year. This is below the 3.3% projected annual growth for 1990 through 2020 and far below the 8-10 % growth rate needed to increase cereal production to a level that would ensure food security (Bumb and Baanante 1996).

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3 If we exclude Mauritius and Swaziland, two atypical countries having extremely high rates of fertilizer use (more than 150 kg/ha), the variability is considerably less, though still high (mean of 8.75 kg/ha and median of 4.74 kg/ha).

4 Central African Republic, Congo, Guinea, Liberia, Sierra Leone, Madagascar, Uganda, Angola, Botswana, Somalia, Senegal, Mozambique, Zimbabwe.

5 Gabon, Nigeria, Togo, Ethiopia, Burkina Faso, Mauritania.

3. A CONCEPTUAL FRAMEWORK FOR EXAMINING DETERMINANTS OF FERTILIZER CONSUMPTION

Both economic theory and experience from other parts of the world provide us with a wealth of ideas about the factors that influence fertilizer consumption. Desai and Stone (1987) pointed out that it is helpful to think of fertilizer consumption in terms of both its potential and its actual levels. This is particularly true in SSA where actual levels fall far below documented potential.

Figure 4 illustrates a number of important issues to consider when examining the determinants of fertilizer consumption. First is the distinction between agronomic potential (a function of agro-ecology and existing technologies that shapes yield potential) and agro-economic potential (a function of demand for crops produced with a fertilizer, their prices, and fertilizer prices). It is possible, for example to have very high agronomic potential for fertilizer (excellent yield response) but very poor agro-economic potential (low output demand and prices).

The bottom left corner of Figure 4 identifies many of the factors that can transform agronomic potential into effective fertilizer consumption by reducing input costs, increasing output demand or prices, reducing transactions costs that inflate prices, improving human capital, and increasing access to financial capital. These various factors not only affect the demand side of the equation, but many of them can also encourage the development of aggregate fertilizer supply. It is the interaction of effective demand and aggregate supply that determine actual fertilizer consumption levels. In the next section, we examine the empirical links between fertilizer consumption in SSA and a number of the determinants identified in Figure 4.

4. MACRO FACTORS AND FERTILIZER CONSUMPTION IN SSA: RESULTS OF CORRELATION ANALYSIS

What explains the large variation in fertilizer use across countries in SSA? Why have some countries experienced positive growth in fertilizer consumption while others have seen an overall decline? What factors (e.g., agro-climatic characteristics, institutional and infrastructures) play a significant role in shaping fertilizer consumption patterns? One of the best ways to quantify the impact of different factors on fertilizer consumption in SSA is to develop a multi-national model of fertilizer demand. As discussed in Section 5 limitations in types of data available and length of data series make it extremely difficult to develop reliable fertilizer demand models for SSA. Consequently, we present the results of a bivariate analysis following the method used by Desai and Gandhi (1988). Desai and Gandhi examined the correlation coefficients between fertilizer use per hectare and a number of hypothesized determinants of fertilizer consumption. In this section we update and expand their analysis incorporating both factors and time periods that were not analyzed by them. While most of our results confirm Desai and Gandhi's findings, there are some discrepancies that need to be resolved and explained.

The methodology used by Desai and Gandhi was to examine fertilizer use on the basis of a five-year average that smooths extreme year-to-year variations in consumption. While Desai and Gandhi used only one five-year-period (1979-1983), we use five, five-year periods for the years 1970-1994. By examining the correlation over a longer period of time, we are able to better identify the influence of different factors on fertilizer use over time. Desai and Gandhi grouped the factors affecting fertilizer use into the following broad characteristics: agroecological zones, historical and structural characteristics, crop pattern characteristics, development effort and infrastructure, trade and debt characteristics, and fertilizer sector characteristics.[6]

4.1. Agroecological Zones and Other Geographic Factors

4.1.1. Regional Effects

For the purposes of reporting agriculture production input and output data, the FAO has grouped Sub-Saharan African countries into five broadly defined regions based on geographical location and the most salient agro-ecology characteristics of each county. These regions are: Central Africa, Coastal West Africa, East Africa, Southern Africa, and the Sudano-Sahel region (Table 2 identifies the countries that are included in each region)[7]. To examine whether the level of fertilizer used (kg/ha) differs significantly by region, we used the same dummy variable regression procedure employed by Desai and Gandhi. From the F-statistic we find that there is

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[6] Due to data limitations we do not address trade and debt and fertilizer sector characteristics in this paper.

[7] FAO units working specifically on soil and natural resource issues have developed classification systems that stress climate, physiography, soils, and hydrology, rather than geo-political boundaries. Analysis of agroecological factors affecting fertilizer consumption could be improved if country-level data were reported in a more disaggeregated manner that took into account a greater range of agroecological variables.

no statistically significant difference in fertilizer dose among the five regions, regardless of the time period. The lack of strong statistical significance across these zones is due to the extremely high variability of fertilizer use patterns within each zone, producing very wide 95% confidence intervals for estimated mean doses by region.

Are there any regions where fertilizer doses are significantly greater than the other regions? The only region for which the coefficient is statistically significant is Southern Africa, and it is significant for all time periods except 1970-1974. For example, in 1990-1994, fertilizer usage was significantly higher in Southern Africa at an implied mean dose of 17.25 kg/ha (Table 2). The lowest level of consumption for this period occurred in the Central African region at a mean of 3.23 kg/ha, but the Central African region result is not statistically different from levels for all other regions but Southern Africa. The adjusted R-squared terms, which represent the percent of variability in the doses explained by dummies representing the different regions, are extremely low (less than 0.16 for all periods); they have been falling since the early 1980s. This implies that to date, (1) fertilizer doses have been primarily a function of variables other than agro-climatic environment; and (2) that the broad geographic classifications used to report aggregate fertilizer consumption data do not adequately capture the relationship between fertilizer use and agro-climatic conditions. We tend to think the latter hypothesis is the stronger one. In other words, regional classifications used in the FAO fertilizer database are too broad to capture the variability in agro-climatic conditions across countries in the same region, as well as variation in conditions within individual countries.

Moreover, there is substantial variation in agro-climatic conditions within individual countries that is also not captured by the FAO regional classification[8].

4.1.2. Access to Ports

It is often hypothesized that landlocked countries with poor access to ports are less likely to consume fertilizer because it is more expensive to import. To test this hypothesis, we examined the correlation coefficient of fertilizer dosages and a dummy variable indicating whether a country was landlocked or not. Although fertilizer use appears to be negatively correlated with the dummy representing difficult access to ports, the correlation coefficients for each period examined were not significant.

To assess the link between climate and fertilizer use, we examined the correlation between fertilizer doses and an index of annual average rainfall for each country. The coefficients were statistically significant and greater than 0.5 for all periods, except the last (Table 3). This confirms that SSA farmers generally increase fertilizer use in years of better rainfall, but it may also mean that many are delaying the purchase and applying of fertilizer beyond the optimal period (planting) in an effort to determine whether rains are good or not. The lack of significance for the rainfall variable during the 1990-1994 period may be due to the policy effect

8 FAO has developed a soil classification system that would be more appropriate for this type of analysis but getting national fertilizer consumption data translated to this type of classification system is extremely difficult, if not impossible.

of structural adjustment programs which might have had a stronger impact on fertilizer use then rainfall.

4.2. Historical and Structural Factors

Is fertilizer use related to the country's colonial past? This question is relevant as it helps identify whether the 'initial conditions' (or the conditions present at the time of independence) have had an effect on fertilizer use. Since the colonial powers (primarily French, British, and Portuguese) pursued different colonial policies, one would expect countries at independence to have varying levels of 'initial conditions', that would affect the fertilizer use for the periods under study. Our results confirm our hypothesis: Anglophone countries have a higher rate of fertilizer application than Francophone or Lusophone countries (represented as Other in Table 4). While the specific 'initial conditions' remain to be identified, it is clear that British colonization predisposed countries to take advantage of input technologies like fertilizers. One factor, that might explain this link, is that Anglophone countries in East and Southern Africa (Kenya, Zimbabwe, and Zambia, in particular) had higher populations of European settlers who established large commercial farms and used fertilizer-intensive production techniques.

4.3. Demographic Factors

It is hypothesized that countries with high population densities, especially in rural areas, will be more likely to pursue agricultural intensification to meet the high food demands. Since agricultural intensification implies the use of chemical fertilizers, we anticipate that countries with higher population densities will have higher fertilizer application rates. To test this relationship, correlation coefficients were calculated between fertilizer doses (kg/ha) and population densities (population/ha) measured in terms of both rural and total population. While all periods show a positive relationship between population density, only one (total population in the 1970-1974 period) was significant (Table 3). Our conclusion is that while high population density may encourage fertilizer use in some areas of SSA, it is not a dominant pattern that can be captured in aggregate data.

We also tested the relationship between education level and fertilizer use. We hypothesized a positive relationship as fertilizer technology. To be effective, it requires management skills usually associated with higher education levels. Here we used the percentage of children attending primary and secondary schools as proxies for education level. The correlation, coefficients for both variables were positive and highly significant (secondary more than primary). We were surprised by the strength of the secondary education coefficient (> 0.6), as most of the SSA farmers have not even completed primary school. One hypothesis is that higher rates of secondary school attendance might be contributing to higher quality support services to farmers. Examples of this would be extension, input distribution, and output marketing, which promotes more fertilizer use.

4.4. National Income Factors

In this section we examine whether countries with differing income levels (as measured by GNP/capita), growth rates (GNP/capita growth rates), or the share of agriculture in an economy's GDP is correlated with fertilizer use. We hypothesize that relatively richer countries, or those who experience faster growth, will exhibit higher levels of fertilizer application. Our analysis failed to confirm this hypothesis however, since all the correlation coefficients were negative and not significant.

We also investigated whether foreign aid (specifically, total official direct assistance per hectare of cultivated land) is correlated with fertilizer use. Here also, the results are not statistically significant, with a mix of signs across periods.

4.5. Infrastructure Factors

A good and reliable infrastructure can play a major role in encouraging fertilizer use and increasing farm productivity. For example, an extensive road network, especially in the rural areas, can help reduce transport costs (and hence fertilizer costs) and also help in providing fertilizer in a timely fashion. Since for many high-yielding cereals, fertilizer, and irrigated water are considered complements, the presence of an irrigation system can also encourage fertilizer use. Our results indicate that countries with denser road networks (km/ha) use more fertilizer per hectare. The results are significant for the first two periods (1970-1974 and 1975-1979), but are not significant for the later three (1980-1994). A possible explanation, for the lack of significant correlation since the 1980s, might be that the rapid urbanization experienced by many of these countries in the eighties, led governments to build roads in and around cities at the expense of infrastructure development in the countryside. Available data do not permit us to differentiate between a rural and urban infrastructure.

As for the irrigation correlation, the results are not significant and the signs are unexpectedly negative. The lack of significance for this correlation coefficient is probably due to the fact that irrigated land is such a small share of total area that any higher doses used on the irrigated area are overwhelmed in the analyses by the average application rates for non-irrigated areas. Desai and Gandhi obtained a similar result for the period they investigated. They hypothesized that the weak correlation could be an indicator of "significant fertilizer use on un-irrigated land in some countries." This might be the reason for the strong positive relationship between fertilizer use and rainfall as explained earlier.

4.6. Crop Choice Factors

Analyses of aggregate national data show a few statistically significant links between the relative importance of particular crops in the cropping system and average fertilizer doses. This can be seen in Table 5, which summarizes the results of correlations between fertilizer use and the percentage of cultivated land devoted to particular crops. The only crops or periods examined that exhibit a statistically significant, positive correlation is wheat in 1975-1979 and 1985-1989, roots, tubers, and cassava in 1970-1974, cotton in all periods but 1970-1974 and 1980-1984, and groundnuts in 1975-1984. Surprisingly, maize and cereals in general do not exhibit a significant, positive correlation with fertilizer doses[9]. The maize results differ from those presented by Desai and Gandhi (correlation of .41 is significant at the 95% level) using 1979-1983 data. The general cereal results also differ from Desai and Gandhi's results (correlation of 0.24 is significant at the 95%).

These results suggest that policy analysts should not rely too strongly on broad generalizations about the role of export crops, domestic cash crops, and subsistence crops in determining fertilizer use patterns. One would expect countries allocating a larger share of cultivated area to the more fertilizer responsive crops (e.g., maize) to exhibit higher average fertilizer use per hectare. The fact that this cannot be confirmed with aggregate national statistics suggests that there are other factors shaping fertilizer use patterns in at least some of the major maize producing countries. Moreover, one would expect countries with an important share of cultivated area allocated to export crops, to exhibit higher fertilizer use patterns as countries and farmers with income from export crops, to be better able to pay for imported fertilizer. The cotton sector, for example, in many SSA countries has been vertically integrated−input, output, and credit markets are linked thereby reducing the costs and risks of administering the credit program. Credit is available to all farmers, encouraging them to use fertilizer. A mitigating factor might be that some export crops, such as cotton, tend to be less fertilizer responsive than non-export crops, therefore little fertilizer is used on them. Based on their results for 1979-1983, Desai and Gandhi concluded that the strong association between fertilizer use and cereals, particularly maize, suggested that a policy of promoting maize adoption could facilitate the acceleration of fertilizer consumption. Using a slightly smaller set of countries however, this result has not been supported by our analyses of other time periods.

There is a need to better understand the link between African fertilizer use and crop choice at the farm level, as the anticipated relationships are not being exhibited in aggregate national and regional data.

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[9] Although maize does account for approximately 25% of SSA fertilizer used, only a small portion of total maize area is fertilized.

5. MODELING FERTILIZER DEMAND

The above correlation analysis, while useful in identifying the factors associated with fertilizer use, primarily measures the strength or degree of linear association between fertilizer use and the correlated variable. From a policy perspective, however, such analysis may not be very practical and useful as it does not allow one to predict fertilizer consumption from hypothesized policy changes. That is, it does not tell us by how much fertilizer use will increase if, for example, more land was irrigated and roads built. Also, our correlation analysis omits the most important variable in the determining fertilizer use--prices, due to a lack of data. From economic theory we know that the demand for any input is a function of price of the input, price of competing inputs and prices of the outputs. Therefore, there is a need to take into account how fertilizer use is related to prices.

To address some of these issues, fertilizer demand models can be constructed to relate fertilizer with price and non-price factors using aggregate level data. Such models, varying in the degree of econometric sophistication, have been estimated for different countries, including the United States (Griliches 1959) (Heady and Yeh 1959), India (Parikh 1965), Bangladesh (Hossain 1985), (Parikh 1988), and Malawi (Chembezi 1990). We are not aware of any cross-country analysis of fertilizer demand for SSA, and Chembezi's study on Malawi is the only one we found for an individual African country. Modeling fertilizer demand using aggregate cross country data for SSA would be a useful exercise if it permitted us to better quantify the relative influence of determinants discussed above.

We estimated such a model using annual time series, from 1977-1992, for seven countries that have relatively good data[10]. We hypothesized that the demand for fertilizer in these countries was a function of prices (specifically price of fertilizer, maize, and cotton), as well as non-price factors of rainfall, foreign exchange reserves, secondary education, and kilometers of roads. The main results of the model (a least squares dummy variable model, with fertilizer demand being the dependant variable) are as follows:

- The coefficient for the fertilizer or maize price ratio is negative and significant. This is consistent with economic theory as it implies that the demand for fertilizer will increase if its price decreases. The result also implies that the fertilizer demand will increase if the price of maize increases. Interestingly, when we estimated a slightly different model using individual variables for the maize and fertilizer prices, instead of a ratio, the coefficients on these variables were not significant.
- A perverse relationship exists between fertilizer use and cotton price, as both variables are inversely related, though the negative coefficient on the cotton price is not significant. There is also an inverse relationship between fertilizer use and land under cotton cultivation, with the negative coefficient on the "land under cotton cultivation" variable actually being significant. This implies that increase in cotton cultivation actually leads to a decrease in fertilizer consumption and not an increase.

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[10] This section is based on a forthcoming paper by Naseem. The main results presented here should be regarded as preliminary. The seven countries are Burkina Faso, Ivory Coast, Kenya, Malawi, Nigeria, Zambia, and Zimbabwe.

- The coefficients for the area under irrigation and the proportion of land under maize were positive and significant.
- Coefficients for roads and the percentage of children in primary and secondary school were positive but not significant, while rainfall was negative and not significant.
- The coefficient on the foreign exchange variable is positive and significant, implying that there may be a supply constraint on fertilizer use. The implications of this are that countries with foreign exchange constraints or under debt are unable to use fertilizer at higher levels. While resolving the debt issue is important, it should be recognized that in most SSA countries, fertilizer import is only a fraction of the total import bill. By curtailing fertilizer imports, countries may not be saving that much in foreign exchange and may even be slowing growth in food production, thus increasing dependance in food imports.

The seven countries selected are not broadly representative of SSA. They were selected primarily because they had a relatively complete data series. The fact that many of the results differ from those suggested by correlation analysis, using a much broader set of countries, is also reason for cautious use of results of this model. To adequately test our hypothesis about the relative importance of different factors that affect fertilizer use, one needs a full set of data on the variables used in this model for all countries in SSA. Unfortunately such data are not available.

To illustrate the sum of the data problems, it is constructive to look at trends in fertilizer price and consumption for the seven SSA countries in the dataset. The first problem relates to which fertilizer price to use in the analysis. Fertilizer comes in different formulations containing different amounts of nutrients. While the data on aggregate consumption of the three main nutrients (nitrogen, phosphate, and potassium) is available for most countries, continuous time-series data on price and aggregated consumption of the nutrients is only available for the seven countries mentioned. Very little price data was available on the FAO database for P (Phosphorous) and K (Potassium). For nitrogen, the price of urea is available, with occasional reporting of prices for ammonium sulfate and ammonium nitrate, the other main formulations of nitrogen. Given these data restrictions, any demand modeling would have to use the price of urea as a proxy for the price of nitrogen and restrict the analysis to estimating the demand for *nitrogen* fertilizer. However, urea may not be an ideal proxy for nitrogen fertilizer. Consider Figures 5, 6, and 7 where we present the trends in the price and consumption of urea and ammonium sulfate for Zimbabwe, Zambia, and Kenya. Kenya, for example, has seen periods (1971-1978) where the consumption of ammonium sulfate was greater than urea, but for much of the 1980s urea was consumed more than ammonium sulfate. Thus, by using urea as a proxy, fertilizer demand would be underestimated.

The other important assumption that needs to be made relates to how fertilizer price (expressed in nominal local currency terms) can be compared across both time and the different countries. There are two possible approaches: (1) is to calculate the relative price of fertilizer. Relative price here refers to the fertilizer price divided by a weighted price of all crops that consume that fertilizer. Such an approach deflates the fertilizer price, and permits price comparisons between countries without converting the common currency unit. However, it is difficult to identify which crops using fertilizers and how much is used per crop, given the aggregate nature of the data. Our correlation analysis from the previous section revealed that fertilizer use is positively correlated with maize, wheat, and cotton, and negatively with important cereal crops like sorghum and millet. Unfortunately, with the exception of wheat (a minor cereal crop for much of SSA) none of the correlation coefficients were found to be significant. Therefore, one cannot determine with confidence on which crops the fertilizer is being used and; (2) may be to use the price of maize as a proxy for the weighted price of all crops. This approach can be rationalized on the grounds that maize is the main cereal crop grown in much of SSA, especially in southern Africa, and the second most important crop consuming fertilizer.

Is the urea-maize price ratio an appropriate indicator of incentive to use nitrogen fertilizer in SSA? Figures 8 to 11 show the trends in relative prices and consumption for the Ivory Coast, Malawi, Kenya and Zimbabwe. From the graphs we see that, for some countries, the price and consumption of fertilizer is related in a perverse way. For example, in Ivory Coast periods of declining urea-maize price ratios have actually led to decreases in nitrogen fertilizer consumption, rather than increases as theory would predict. This perverse relation is also apparent during certain periods of time in Malawi (1985-1988) and Kenya (1979-1983). The implication of this observation is that either the urea-maize price is not an appropriate variable to explain fertilizer consumption, or other factors are more important in determining nitrogen fertilizer consumption rather than just fertilizer price.

6. CONCLUSION

This paper has examined, over a twenty-six-year period (1970-1995), the trends in fertilizer usage in SSA, as well as, the relationship between fertilizer use and key factors that influence it. Overall, fertilizer use has increased significantly from its initial levels in 1970, although the increase has not been uniform with variations across both time and the countries examined. Despite increases in use, fertilizer doses per hectare remain much lower than application rates for other developing regions, especially Asia, where fertilizer has been associated with substantial increases in agricultural productivity.

The analysis conducted in this paper sheds some light on the determinants of fertilizer use in SSA. In general, we found that fertilizer use per hectare was positively correlated with:

- the amount of rainfall per year.
- the density of road infrastructure.
- the number of children in school (both primary and secondary).
- the percentage of cultivated area devoted to cotton and/or wheat production.

One of the largest and most consistently significant correlation coefficients was rainfall, which will likely remains a key determinant of fertilizer adoption and efficiency well into the future as a very small share of cultivated area in SSA benefits from irrigation. This finding underscores the need to find seed or fertilizer technologies that are more responsive in the type of low moisture situation that characterizes much of SSA.

Although the size and significance of the road density coefficient have been declining over time, it was highly correlated with fertilizer use up to the early 1980s. Given the lack of significance for the variable in recent years, it is difficult to evaluate the extent to which future investments in a road infrastructure might contribute to fertilizer use. However, it appears to be a variable that warrants careful analysis at a more dis-aggregated level (e.g., across regions within individual countries).

The education variables suggest that investments in schooling may have indirect effects on stimulating fertilizer use (e.g., by improving human capital at the farm level and among those providing services to farmers).

Cotton production schemes have been used to introduce fertilizer to small farmers in a variety of SSA settings where the use has subsequently been expanded to other crops, particularly coarse grains. The lesson to be learned from this variable is not so much that cotton, per se, is the best way of getting fertilizer into the farming system, but that some type of cash crop scheme that provides farmers with reliable input, credit, extension, and output marketing services can play a significant role in promoting fertilizer adoption. Wheat is not a major crop in most of SSA, but it is associated with high levels of fertilizer use because it responds well to fertilizer and is often grown in areas with high rainfall or that benefit from an irrigation infrastructure.

A number of factors that we expected to be highly correlated with fertilizer did not exhibit statistically significant coefficients in the broad analysis using data from more than 30 countries.

Among the most surprising is:

- the share of area cultivated in maize.
- the share of cultivated area benefitting from irrigation.

The maize results are surprising because maize is generally considered the most important user of fertilizer in SSA (accounting for about 25% of total use), and it is a crop that Desai and Gandhi (1988) found to be highly correlated with fertilizer use between 1979 and 1983. Furthermore, our preliminary model, based on data for seven countries, also had a statistically significant and positive coefficient for the percentage of area cultivated in maize. It is possible that the sharp drops in fertilizer use on maize, that occurred in major maize producing countries such as Ghana, Zambia, and Zimbabwe during the late 1980s and early 1990s (when these countries went through structural adjustment reforms), introduced a lot of 'noise' in the data that overwhelmed the underlying relationship. We believe the link between fertilizer use and maize production warrant careful monitoring in the future because maize is one of the most fertilizer responsive crops grown in SSA and it has been the crop of choice for introducing fertilizer to farmers in a number of recent extension efforts (e.g., the Sasakawa/Global 2000 programs in Ethiopia and Mozambique).

The lack of correlation between fertilizer use and the percent of area irrigated is also a bit of an anomaly as the irrigated production schemes we are familiar with in SSA (e.g., Mali's Office du Niger and the Senegal River Basin), use large quantities of fertilizer per hectare. Also, this is a case where the coefficient was significant in our seven-country model, suggesting that there may be more to the relationship than revealed by the aggregate data for the entire SSA region. It is possible that the total amount of irrigated area in SSA is so small that it is not possible to show a statistically significant relationship with the aggregated data covering so many diverse countries.

Although our analyses provide some important insights into recent fertilizer use, trends, and determinants at an aggregated level, there are still many unknowns. A critical first step in developing a better understanding of factors that are driving fertilizer use, at both the country and the regional level, is improving the fertilizer data base in each country. Among the key improvements needed are better dis-aggregations by agroecological zone, crop, and type of fertilizer used. Data series on fertilizer prices by location and type of fertilizer would also be helpful. When these types of data become available at the country-level, both national and regional policy analysis will improve.

Appendix: Tables and Figures

Table 1. Fertilizer Consumption and Arable Land Area in SSA from 1970-74 and 1991-95

Country	Arable and Permanent Crop Area, '000 ha (1970-74)	Fertilizer Consumption, MT (1970-74)	Fertilizer Consumption, kg/ha (1970-74)	Arable and Permanent Crop Area, '000 ha (1991-95)	Fertilizer Consumption, MT (1991-95)	Fertilizer Consumption, kg/ha (1991-95)
Central Africa	**15998**	**30061**	**1.88**	**17815**	**34751**	**1.95**
Cameroon	6108	16110	2.64	7036	23891	3.39
Cent Afr Rep	1850	2145	1.16	2017	1120	0.56
Congo	145	6389	44.66	170	1860	10.95
Equatorial Guinea	229			230		
Gabon	316	33	0.06	466	460	0.99
Zaire	7350	5397	0.73	7896	7420	0.94
Central Africa	15998	30061	1.88	17815	34751	1.95
Coastal West Africa	**41825**	**61477**	**1.47**	**47353**	**485135**	**10.26**
Benin	1667	5181	3.12	1878	17216	9.16
Cote Divoire	2813	27109	9.62	4000	56600	14.11
Ghana	3300	5420	1.64	4408	9934	2.25
Guinea	686	2306	3.37	796	1244	1.58
Guinea-Bissau	278	277	0.39	340	460	1.35
Liberia	366	2905	7.94	371		
Nigeria	29900	15959	0.53	32596	385874	11.86
Sierra Leone	455	1631	3.59	540	2200	4.07
Togo	2360	855	0.36	2424	11608	4.79
East Africa	**27161**	**107379**	**3.95**	**29578**	**281944**	**9.57**
Burundi	1193	736	0.62	1120	3149	2.82
Eritrea				540		
Ethiopia	13588	11542	0.84	12478	135528	11.08
Kenya	3955	50730	12.83	4518	102360	22.66
Madagascar	2419	11631	4.82	3104	9578	3.09
Mauritius	106	25714	243.37	106	28174	265.79
Rwanda	790	309	0.39	1150	1255	1.09
Uganda	5111	6717	1.32	6778	1900	0.28
Southern Africa	**18820**	**255892**	**13.59**	**21144**	**349789**	**16.55**
Angola	3400	19020	5.59	3490	8800	2.52
Botswana	400	1792	4.48	405	960	2.39
Lesotho	359	756	2.11	320	5920	18.51
Malawi	1240	13285	10.71	1698	55782	32.86
Mozambique	3041	10335	3.40	3170	5840	1.84
Swaziland	161	8380	51.83	191	12820	67.06
Tanzania	2741	19902	7.25	3662	41503	11.35
Zambia	4975	47342	9.51	5272	68511	13.00
Zimbabwe	2503	135080	53.88	2936	149653	50.97
Sudano Sahel	**25205**	**84272**	**3.34**	**30252**	**146987**	**4.87**
Burkina Faso	2317	872	0.38	3467	21817	6.30
Cape Verde	40		0.00	42		
Chad	2906	4055	1.39	3246	7585	2.34
Gambia	143	709	4.84	173	840	4.86
Mali	1760	7261	4.13	2646	23240	8.82
Mauritania	232	305	1.42	207	5008	24.15
Niger	2605	275	0.11	4142	3902	0.85
Senegal	2350	19789	8.42	2336	18690	7.99
Somalia	960	3100	3.23	1027		
Sudan	11892	47905	4.02	12965	65905	5.09
Sub-Saharan Africa	**129010**	**539080**	**4.18**	**146143**	**1298606**	**8.89**

Table 2. Differences in Fertilizer Dose (kg/ha) across Agroclimatic Regions of SSA

	1970-74	1975-79	1980-84	1985-89	1990-94
Central Africa					
Coefficient	9.85*	2.61	3.98	4.80	3.23
Implied Dose	9.85	2.61	3.98	4.80	3.23
Coastal West Africa					
Coefficient	-6.67	1.84	0.82	0.40	3.39
Implied Dose	3.18	4.45	4.8	5.2	6.62
East Africa					
Coefficient	-6.38	0.29	0.40	1.41	3.82
Implied Dose	3.47	2.9	4.38	6.21	7.05
Southern Africa					
Coefficient	2.27	11.11**	13.55**	11.98**	14.03
Implied Dose	12.12	13.72	17.53	16.78	17.26
Sudano Sahel					
Coefficient	-6.76	3.86	1.51	1.78	4.20
Implied Dose	3.09	6.47	5.49	6.58	7.43
R-squared	0.12	0.25	0.26	0.20	0.19
Adjusted R-Squared	0.00	0.14	0.16	0.09	0.08
F-statistic	1.01	2.39*	2.57*	1.80	1.73

Notes: Analysis 34 country-level observations on average annual fertilizer dose (kg/ha) applied during the period indicated. A linear model with dummy variables for each region was used to estimate coefficients.
* significance at 90% level
** significance at 95% level

Table 3. Relationship between Fertilizer Doses (kg/ha) and Selected Variables

	1970-74	1975-79	1980-84	1985-89	1990-94
Rainfall (30)[1]					
Coefficient	0.552	0.572	0.624	0.544	0.318
p-value	0.002	0.001	.000	0.002	0.87
Landlocked (35)					
Coefficient	-0.132	-0.1137	-0.0897	-0.1044	-0.0826
p-value	.451	.515	.608	.550	.637
Rural Population (33)					
Coefficient	0.234	0.049	0.060	0.119	0.200
p-value	0.191	0.786	0.742	0.510	0.275
Total Population (33)					
Coefficient	0.339	0.060	0.052	0.122	0.209
p-value	0.054	0.741	0.772	0.499	0.241
Primary education					
Coefficient	0.3659				0.3588
p-value	0.024				0.037
Secondary education					
Coefficient	0.6765				0.6031
p-value	0.000				0.000
GNP per capita (31)[2]					
Coefficient	0.2097	-0.0195	0.0161	-0.0197	-0.1314
p-value	0.258	0.917	0.932	0.913	0.489
Foreign Aid (36)[3]					
Coefficient		0.0194	-0.0731	0.0275	0.1953
p-value		0.911	0.672	0.873	0.268
Roads per ha (34)[4]					
Coefficient	0.6251	0.3340	0.2055	0.2072	0.1995
p-value	0.000	0.054	0.244	0.240	0.274
Irrigation					
Coefficient	-0.049	-0.003	-0.110	-0.840	0.056
p-value	0.795	0.986	0.556	0.653	0.766

Notes
[1]Rainfall index for the period 90-94 is only up to 1993
[2]Exception are 85-89 (33 observation) and 90-94 (31 observations)
[3]Exception is 90-94 (34 observations). Complete data was not available for 70-74
[4]Exception is 90-94 (32 observations)

Table 4. Relationship between Fertilizer Dose (kg/ha) and Colonial Heritage

	1970-74	1975-79	1980-84	1985-89	1990-94
Intercept	8.98***	10.87***	13.80***	14.56***	14.45***
Anglophone (13)					
Coefficient					
Implied Dose	8.98	10.87	13.80	14.56	14.45
Francophone (17)					
Coefficient	-3.69	-6.96**	-9.99**	-9.99**	-8.73**
Implied Dose	5.29	3.91	3.81	4.57	5.72
Other (5)					
Coefficient	-5.84	-7.62*	-9.44*	-10.49*	-10.18*
Implied Dose	3.14	3.25	4.36	4.07	4.27
R-squared	0.04	0.17	0.21	0.22	0.16
F-statistic	0.594	3.256**	4.12**	4.47**	2.94**

Notes: Number in parenthesis indicates the number of countries in each category. Exceptions are for 70-74 where 16 Francophone countries were tested, and for 90-94 where only four Other countries were tested.

*, **, and *** represents significance at 90%, 95% and 99% levels, respectively

Table 5. Relationship between Fertilizer Doses (kg/ha) and Crop Characteristics

		1970-74	1975-79	1980-84	1985-89	1990-94
% Cotton (28)						
	Coefficient	0.0098	0.6069	0.2529	0.4148	0.3987
	p-value	(0.961)	(0.001)	(0.183)	(0.029)	(0.036)
% Groundnuts (32)						
	Coefficient	0.15	0.3075	0.1593	0.1663	-0.0534
	p-value	(0.413)	(0.087)	(0.0384)	(0.363)	(0.772)
% Oilcrops (31)						
	Coefficient	0.2368	0.0670	-0.109	-0.0085	-0.1236
	p-value	(0.200)	(0.72)	(0.954)	(0.964)	(0.508)
% Pulses (33)						
	Coefficient	-0.0080	0.0955	0.0344	0.1491	0.2772
	p-value	(0.965)	(0.597)	(0.849)	(0.408)	(0.118)
% Roots/Tubers (33)						
	Coefficient	0.4568	-0.0725	0.0741	-0.0408	-0.1130
	p-value	(0.008)	(0.688)	(0.682)	(0.822)	(0.531)
% Vegetables (31)						
	Coefficient	0.0125	-0.0273	-0.0488	-0.0345	-0.0281
	p-value	(0.945)	(0.880)	(0.788)	(0.845)	(0.877)
% Total Cereal (33)						
	Coefficient	0.00325	0.2631	0.2428	0.2044	0.1834
	p-value	(0.858)	(0.139)	(0.173)	(0.254)	(0.307)
% Maize (30)						
	Coefficient	0.1586	0.0756	0.1782	0.1759	0.0826
	p-value	(0.403)	(0.691)	(0.346)	(0.353)	(0.664)
% Millet (27)						
	Coefficient	-0.0293	0.0207	-0.0147	-0.0491	-0.1075
	p-value	(0.885)	(0.918)	(0.942)	(0.808)	(0.593)
% Sorghum (26)						
	Coefficient	-0.1370	-0.1277	-0.1415	-0.1131	0.0407
	p-value	(0.505)	(0.534)	(0.490)	(0.582)	(0.843)
% Cassava (30)						
	Coefficient	0.4249	-0.1349	-0.0945	-0.0959	-0.1299
	p-value	(0.019)	(0.477)	(0.620)	(0.614)	(0.494)
% Rice (29)						
	Coefficient	-0.0747	-0.0840	-0.1332	-0.1591	-0.1364
	p-value	(0.700)	(0.665)	(0.491)	(0.391)	(0.480)
% Wheat (17)						
	Coefficient	0.2709	0.4599	0.4019	0.6027	0.3293
	p-value	(0.293)	(0.063)	(0.110)	(0.010)	(0.197)
% Beverages (24)						
	Coefficient	-0.0893	-0.1106	-0.2085	-0.2356	-0.2581
	p-value	(0.678)	(0.607)	(0.328)	(0.268)	(0.223)

Figure 1: Fertilizer Consumption and Arable Land in SSA (1970-1995)

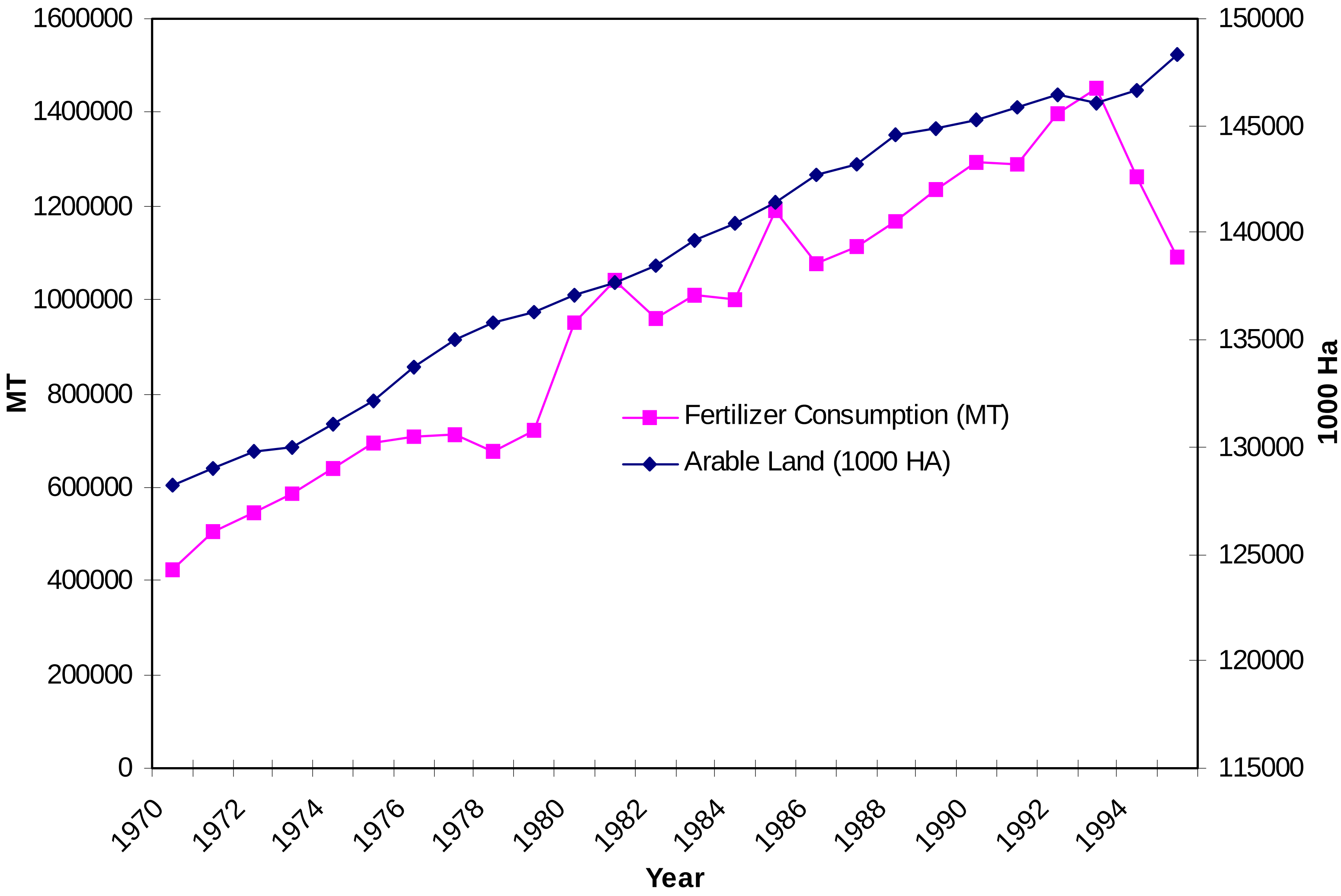
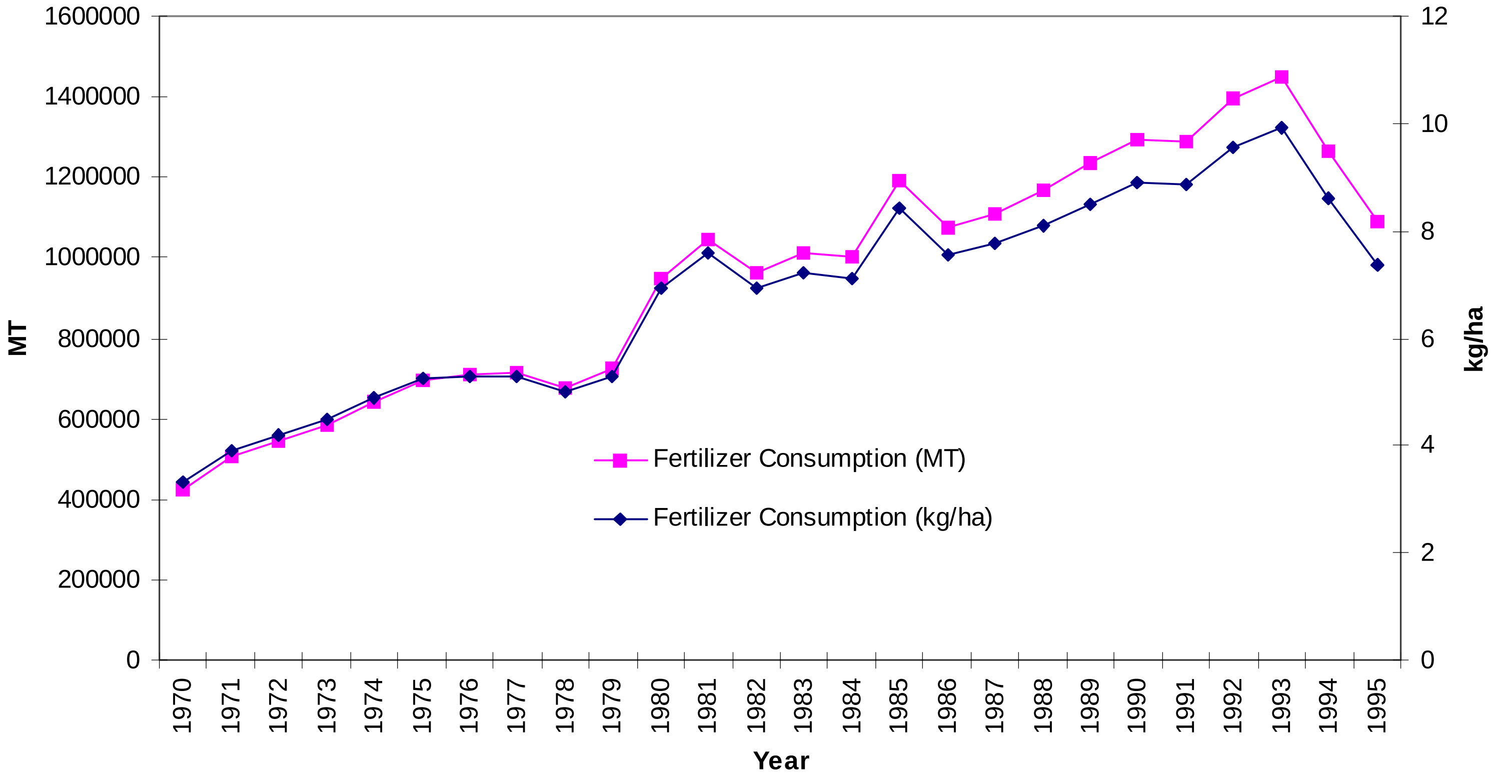


Figure 2: Fertilizer Consumption in Sub-Saharan Africa (1970-1995)



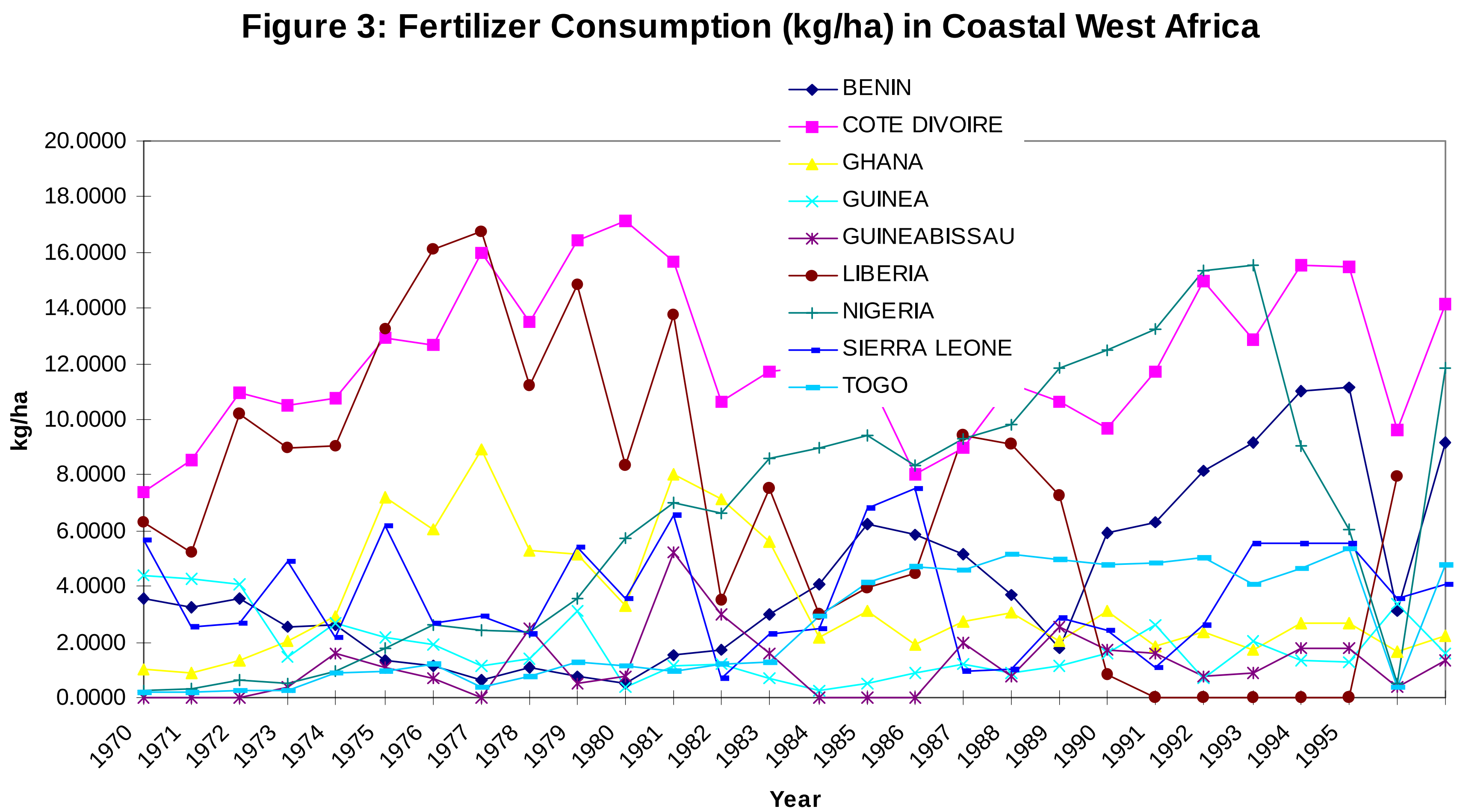


Figure 3: Fertilizer Consumption (kg/ha) in Coastal West Africa
BENIN
COTE DIVOIRE
GHANA
GUINEA
GUINEABISSAU
LIBERIA
NIGERIA
SIERRA LEONE
TOGO
kg/ha
20.0000
18.0000
16.0000
14.0000
12.0000
10.0000
8.0000
6.0000
4.0000
2.0000
0.0000
1970
1971
1972
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Year

Figure 4: Determinants of Fertilizer Consumption

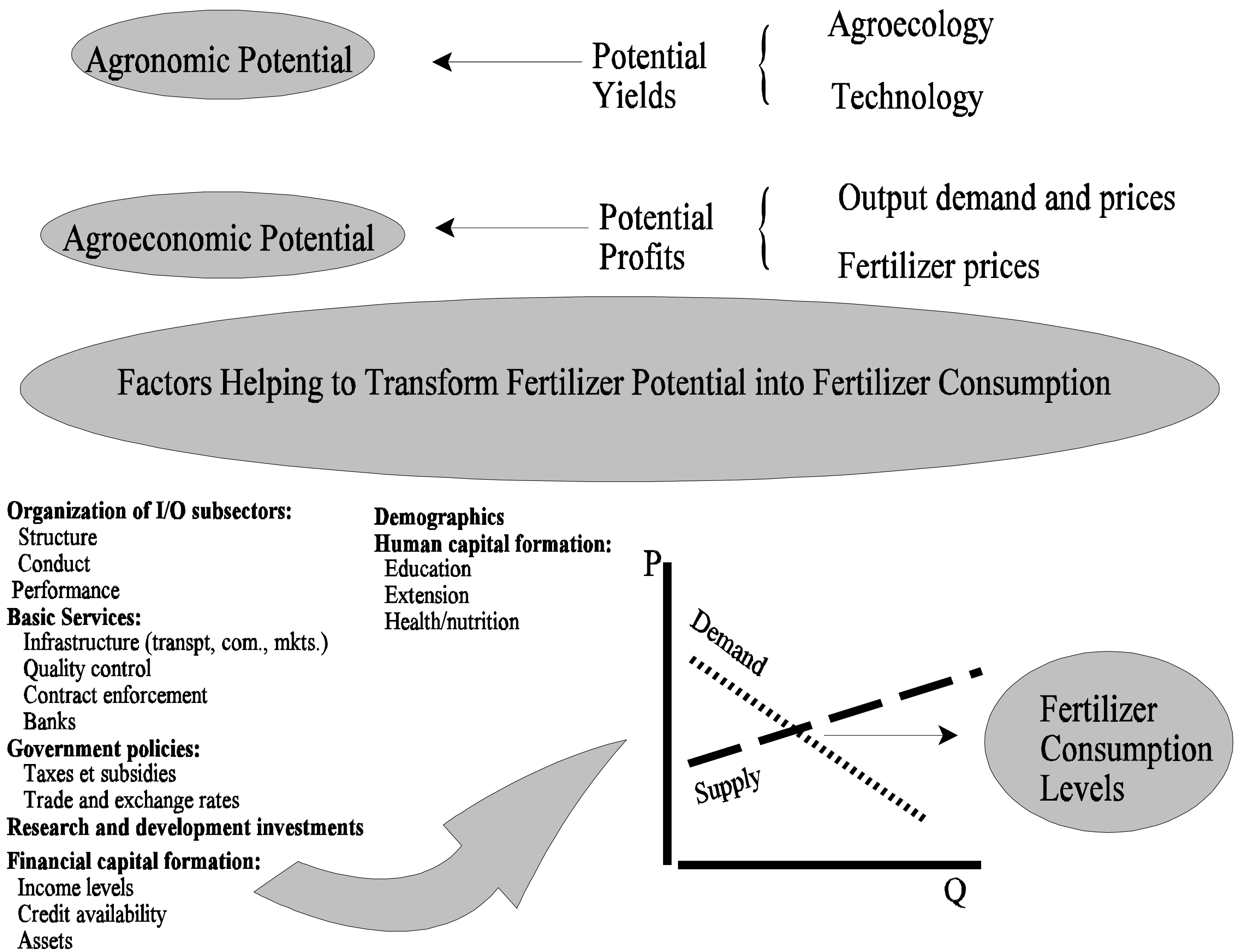


Figure 5: Trends in Urea and Ammonium Sulphate Price and Consumption for Zimbabwe

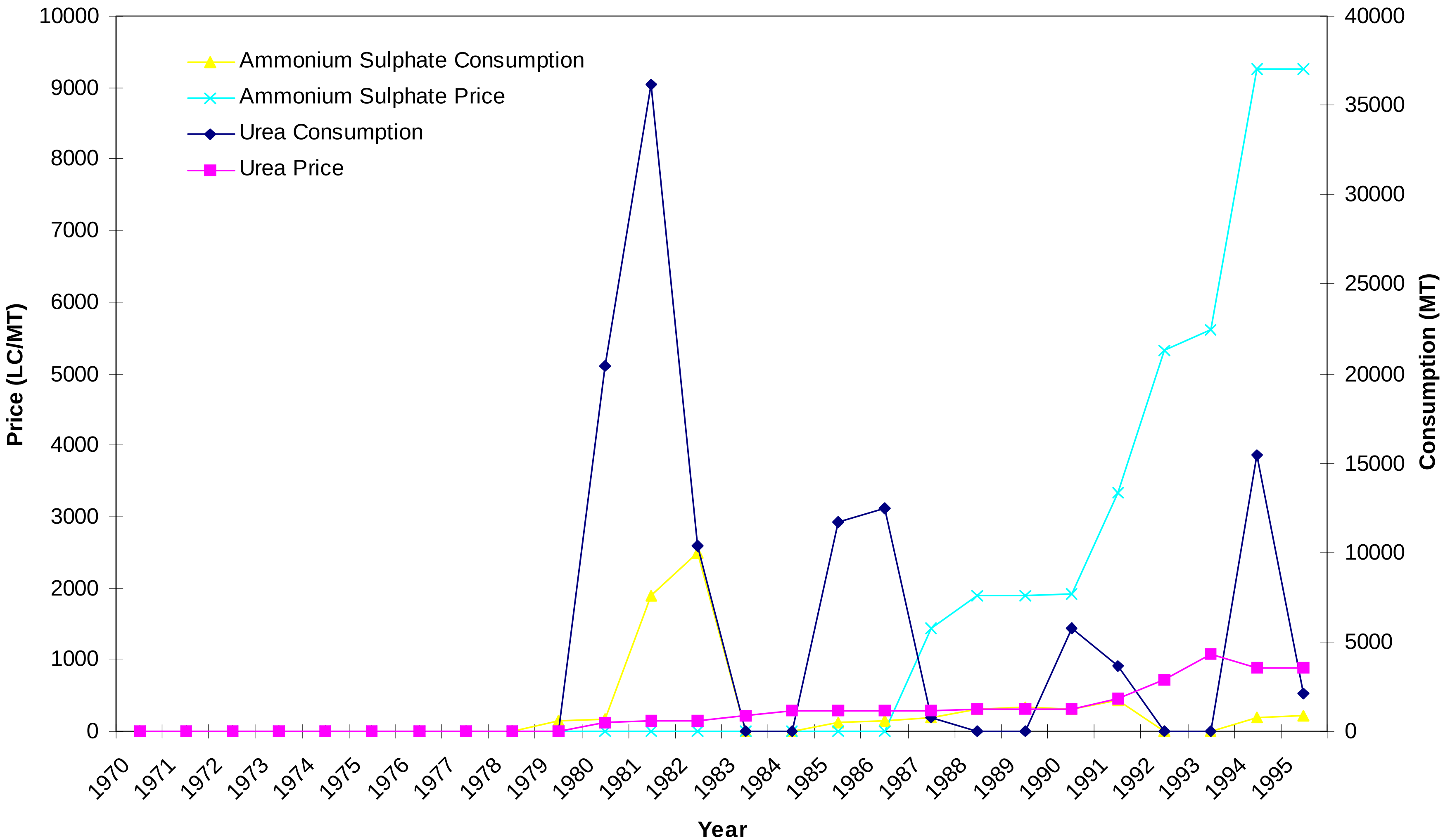


Figure 6: Trends in Urea and Ammonium Sulphate Price and Consumption for Zambia

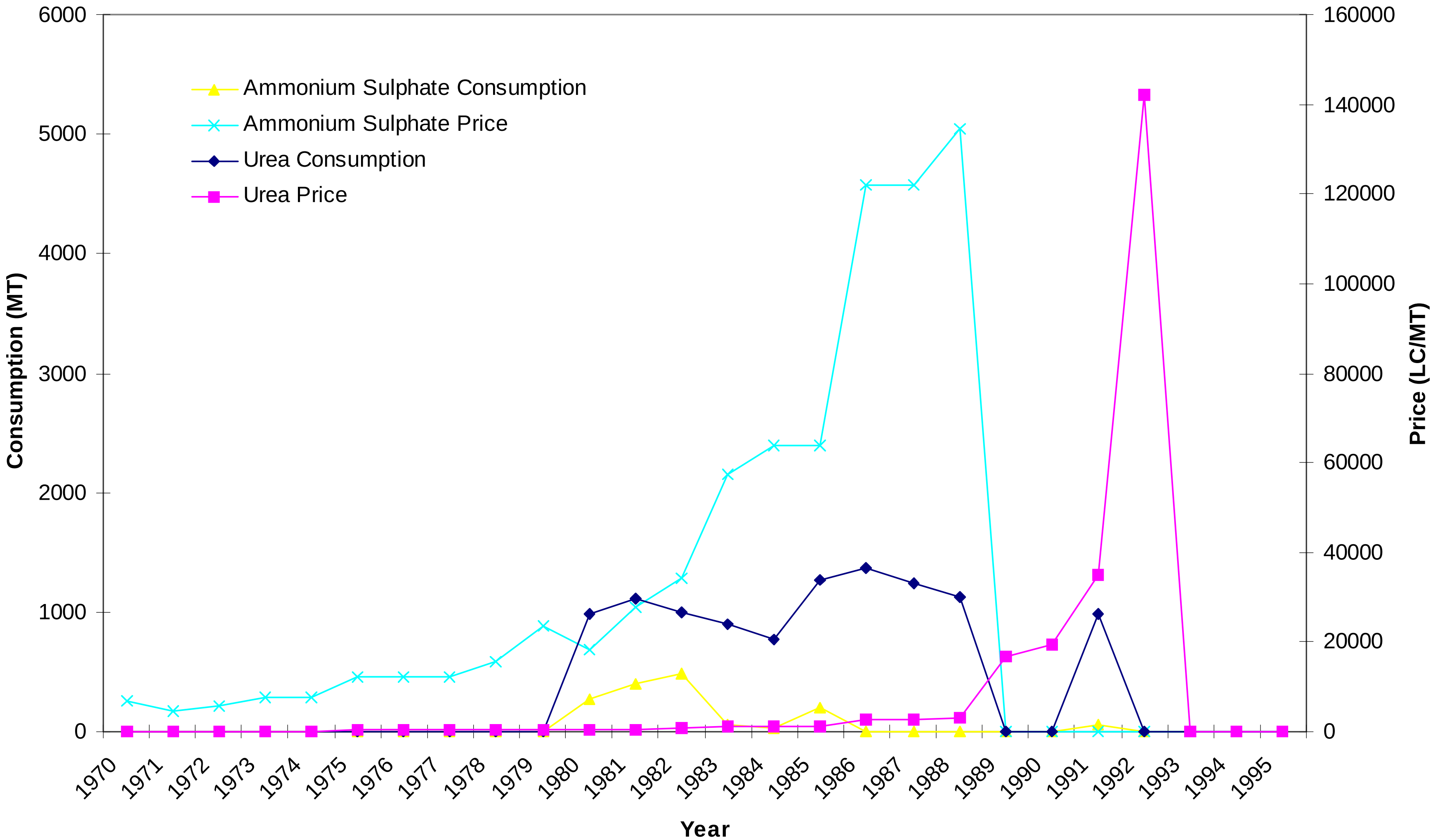


Figure 7: Trends in Urea and Ammonium Sulphate Price and Consumption for Kenya

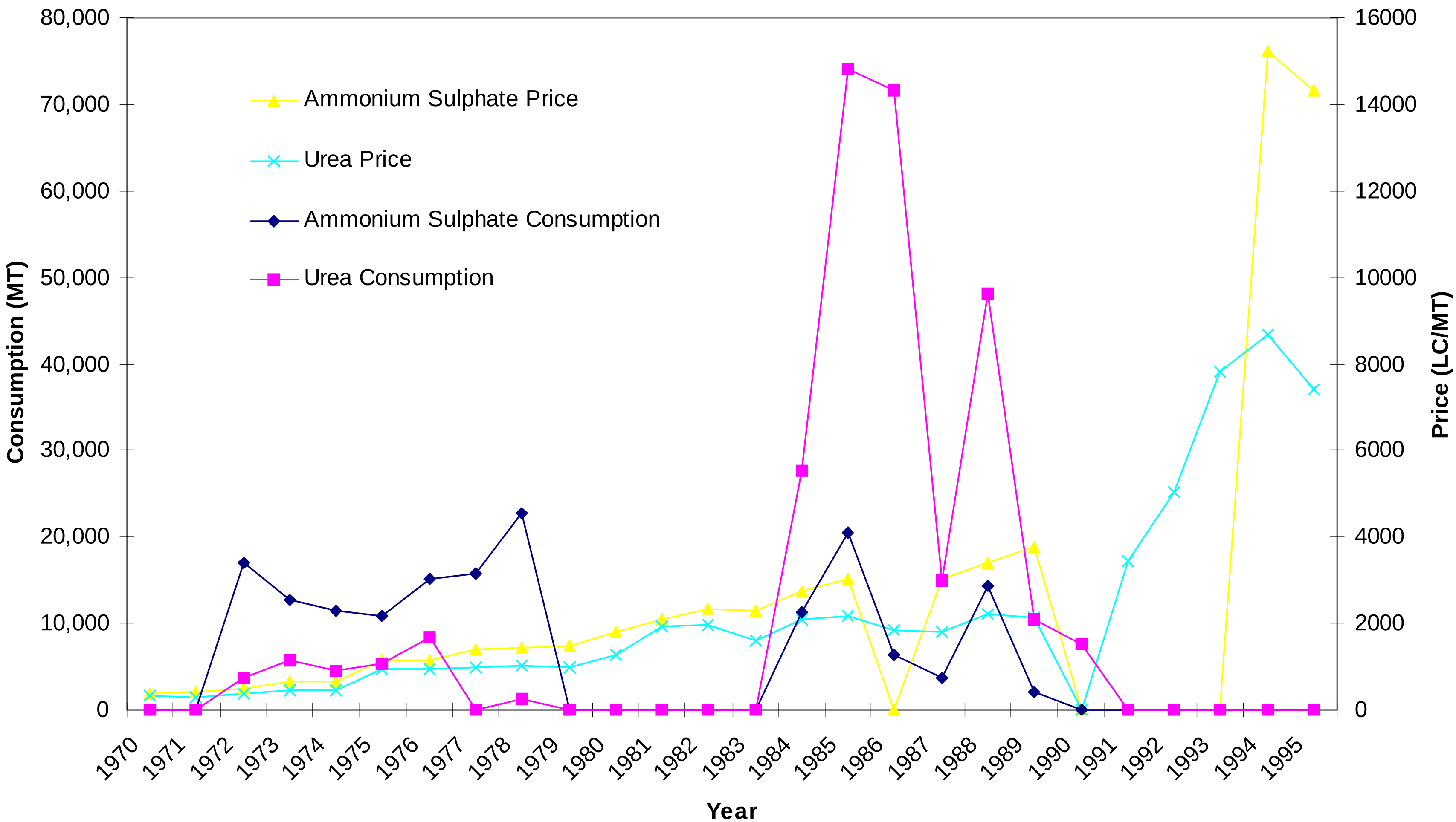


Figure 8: Trends in fertilizer price and consumption in Ivory Coast

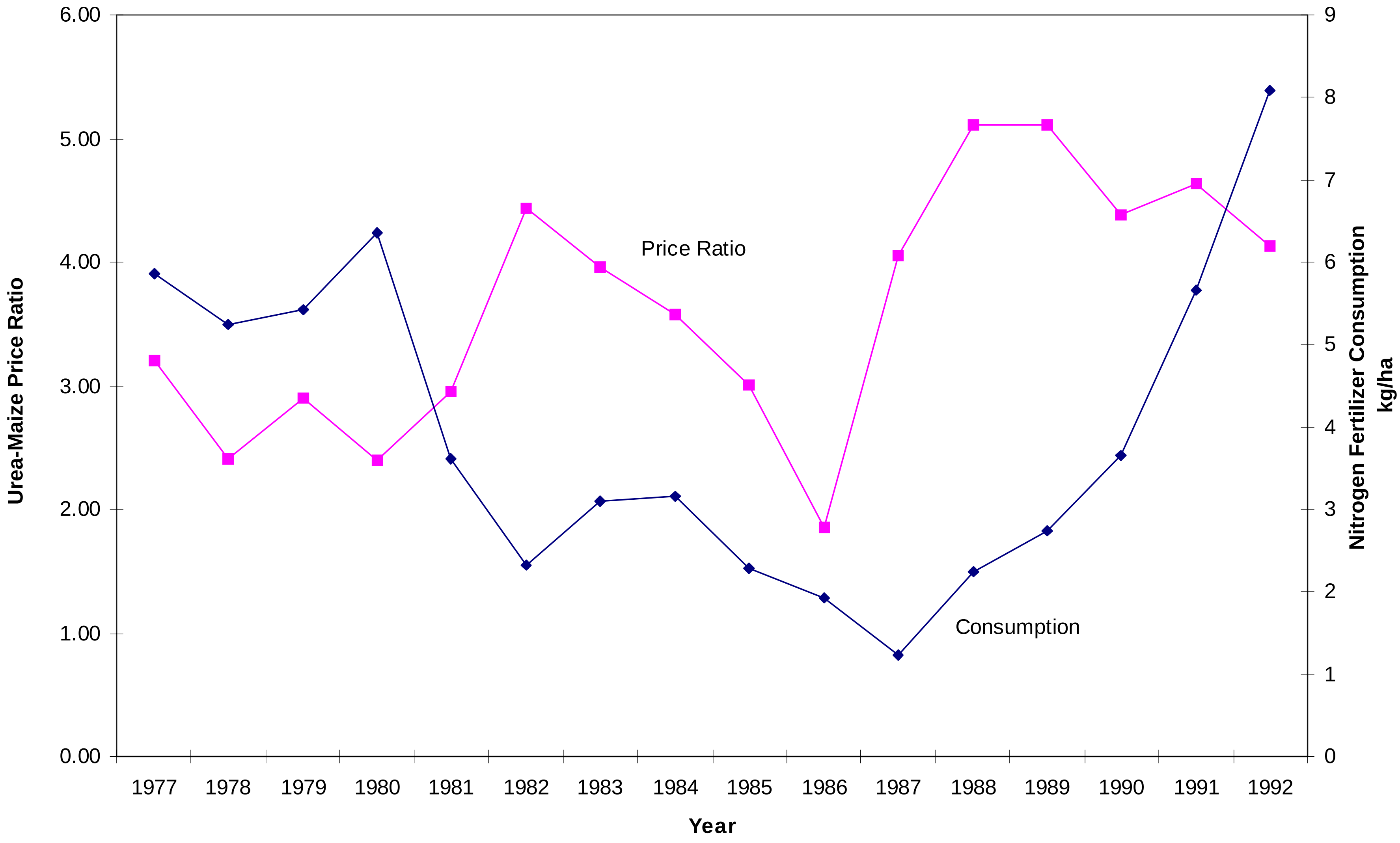


Figure 9: Trends in fertilizer price and consumption in Malawi

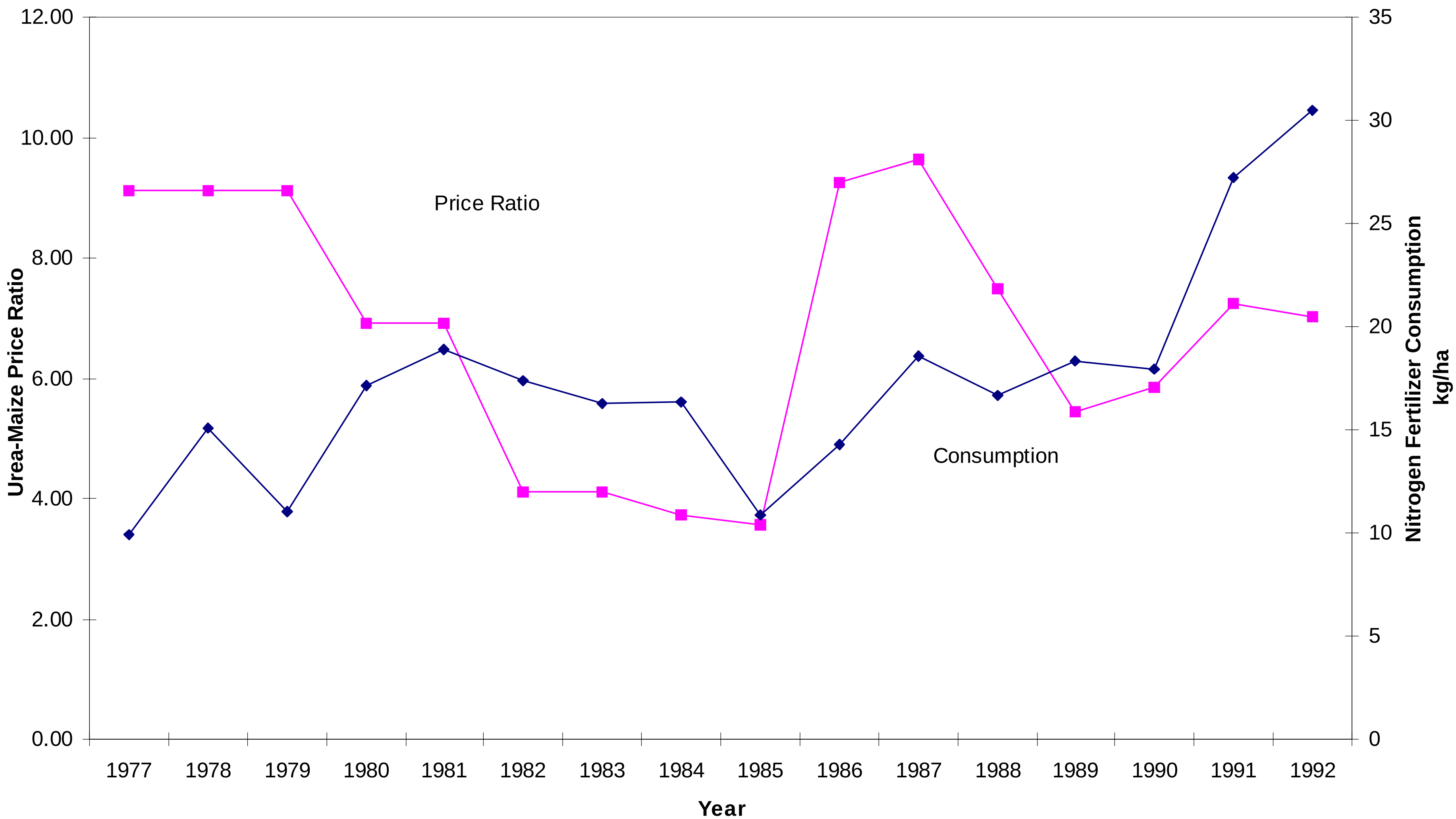


Figure 10: Trends in fertilizer price and consumption in Kenya

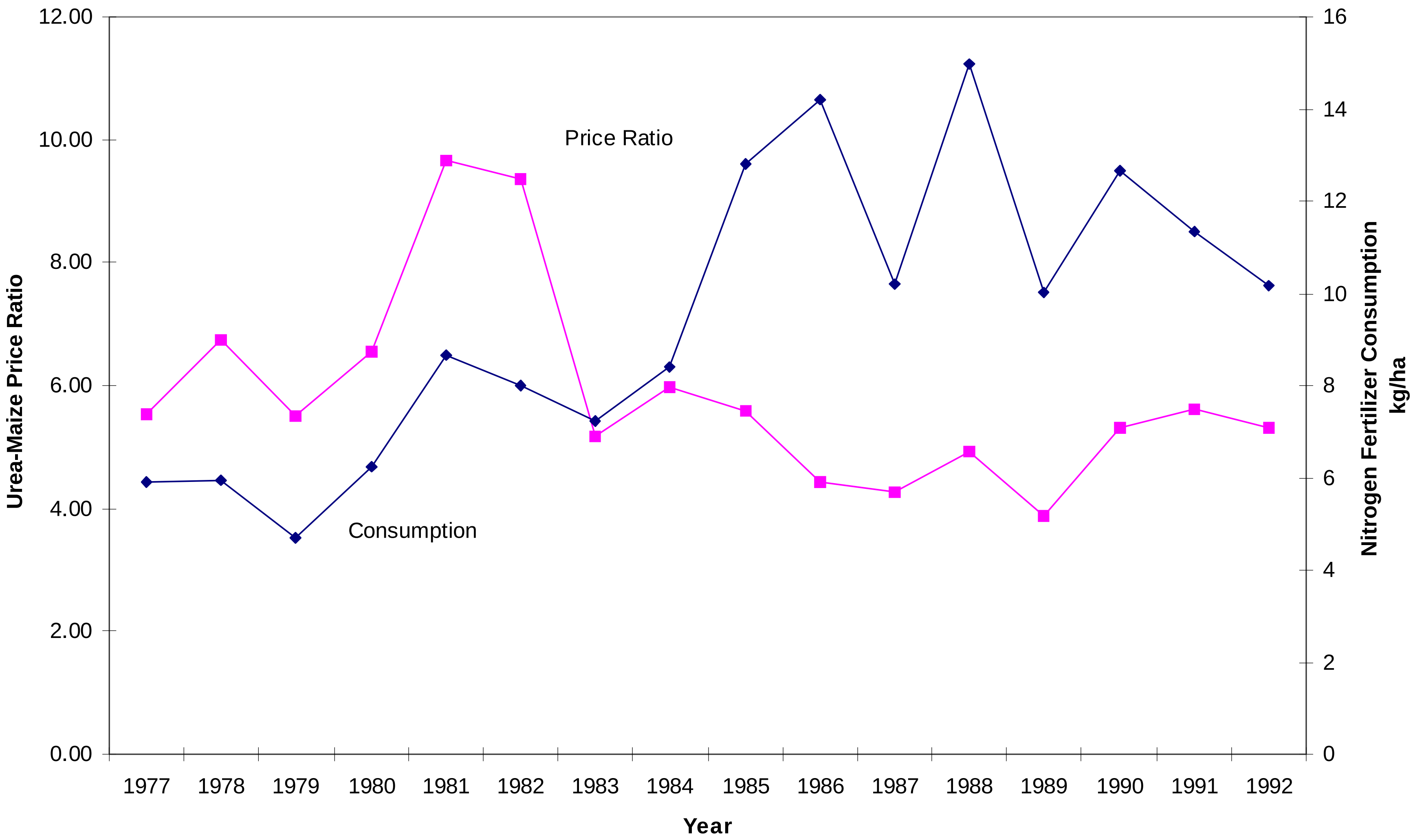
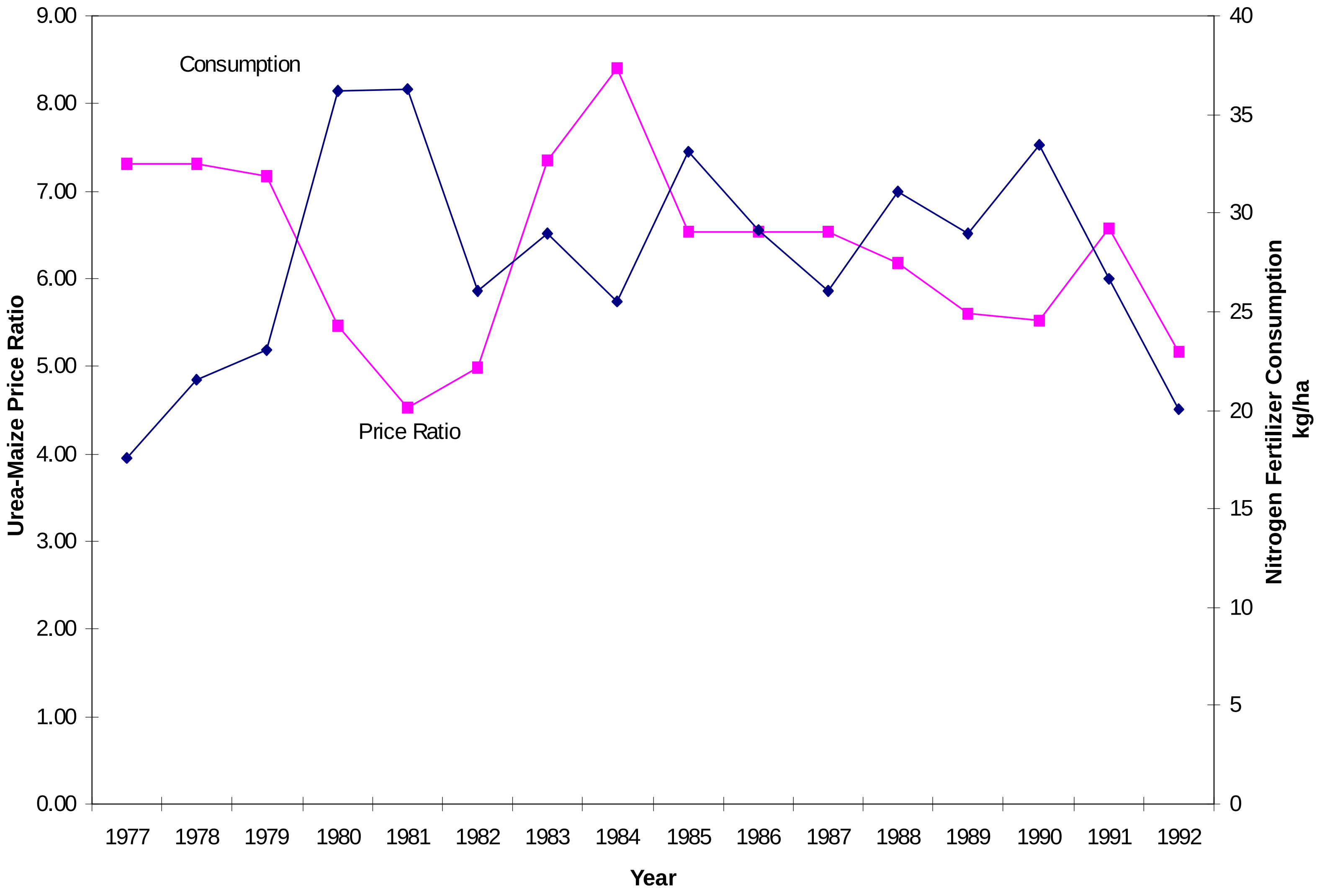


Figure 11: Trends in fertilizer price and consumption in Zimbabwe



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