FERTILIZER CONSUMPTION IN RWANDA:

Past Trends, Future Potential, and Determinants

by

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LIST OF ACRONYMS

APNI	Project Appui au Programme National Intrants
ARMD	Agricultural and Rural Markets Development Project
BNR	Banque Nationale du Rwanda
CNA	Commission Nationale de l'Agriculture
DAP	Diammonium phosphate
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GOR	Government of Rwanda
ICHA	Impot sur le Chiffre d'Affaires
IFAD	International Fund for Agricultural Development
ISAR	Institut des Sciences Agronomiques du Rwanda
MINAGRI	Ministry of Agriculture, Animal Resources, and Forestry
NPK	Nitrogen, phosphorus, and potassium fertilizers
PASAR	Projet d'appri à la sécurité alimentaire au Rwanda
OCIR	Office des Cultures Industrielles du Rwanda
SORWATHE	Société Rwandaise du Thé
TSP	Triple super phosphate fertilizers

FERTILIZER CONSUMPTION IN RWANDA : PAST TRENDS, FUTURE POTENTIAL, AND DETERMINANTS

1. AGGREGATE NATIONAL FERTILIZER CONSUMPTION TRENDS[1]

Fertilizer consumption in Rwanda has always been extremely low in both relative and absolute terms. Aggregate national consumption from 1980 to present rarely exceeded 5,000 tons per year. Average consumption per hectare of cultivated land is generally estimated at < 4 kg. This contrasts sharply with averages (ranging from 9-11 kg/ha during the last decade) for SubSaharan Africa in general, which continues to have the lowest fertilizer consumption of any region in the world.

1.1. Pre-war period (to 1994)

Interest in fertilizer in Rwanda can be traced back to the early 1970s when *Institut des Sciences Agronomiques du Rwanda* (ISAR) began to conduct fertilizer trials. During the early 1980s, FAO funded projects to test and promote fertilizer in the Butaré and Gikongoro prefectures, but there was no evidence of a national commitment to promoting widespread adoption of inorganic fertilizers at that time. Quite the contrary, the Government of Rwanda (GOR) was following a policy of agricultural self-sufficiency that discouraged fertilizer use. Rwandan soils were considered generally fertile. It was believed that fertility could be maintained by using locally available organic fertilizers in combination with crop rotations and anti-erosion techniques. Inorganic fertilizers were expensive and needed to be imported–factors which limited their appeal to a government aiming for self-sufficiency (CNA 1991).

By the late 1980s, however, there were documented signs of declining agricultural productivity. Interest in the potential role of inorganic fertilizer began to grow and many projects that included fertilizer components were launched. During this period, fertilizer used on food crops was generally NPK (primarily 17-17-17), representing 68% of fertilizer imports by the *Projet Appui au Programme National Intrants* (APNI) from 1984-1987. Phosphate fertilizers (DAP and TSP) represented 8% and urea 6% of APNI imports. Fertilizers for industrial crops (NPKs such as 20.10.10) accounted for the remaining 19% of imports during this period. Extensive use of 17-17-17 was stimulated by donors' (European and Japanese) willingness to offer it as in-kind aid. Consequently, it became the fertilizer used in official MINAGRI recommendations.

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[1] We attempted to make a distinction between fertilizer consumption (i.e., off-take or use) and fertilizer imports, but we found only one reference citing consumption figures (Mujyebumba 1997). We identified multiple sources of import data, most of them reporting different numbers. The differences among the various reports appear to be because of differences in criteria used for attributing imports to a particular year. To avoid confusion, Table 1 reports the most recent import data obtained from the BNR which monitors fertilizer imports through requests for foreign exchange and customs data.

Despite the many fertilizer projects (FAO trials and demonstration plots as well as efforts by bilateral donors), aggregate consumption reached a peak of only 6,593 tons by 1991. Consumption data are not available for the rest of the pre-war period. Data from the *Banque Nationale du Ruanda* (BNR) suggest that there may have been growth in consumption just prior to the war because 1993 imports reached an all-time high of 13,192 tons (Table 1). However, consultation with knowledgeable persons failed to provide a solid explanation for this unusual increase in fertilizer imports during 1993. The consensus is that these imports, primarily ammonium and nitrate products, were never used for agricultural purposes, but may have been used for military purposes associated with the war effort.

TABLE 1. FERTILIZER IMPORT AND CONSUMPTION TRENDS (TONS)

Year	Imports	Consumption
1984	4401	4401
1985	5000	5000
1986	3529	3529
1987	4090	4090
1988	5613	5613
1989	7463	1481
1990	90	2149
1991	7490	6593
1992	5693	
1993	13192	
1994	647	
1995	1344	2025
1996	1173	1775
1997	2938	
1998	4780	
1999	2731	
2000	6537	

Sources: Imports for 1984-1989 and all consumption data from Mujyebumba; imports for 1990-2000 from BNR.

1.2. Post-war European Union Import Period (1995-1998)

In sharp contrast to the earlier emphasis on self-sufficiency and organic approaches to soil fertility and agricultural productivity, Rwanda's post-war agricultural policy has been strongly in favor of intensification using modern inputs and the transformation of Rwanda's semi-subsistence producers into commercial farmers. In support of this policy, the European Union managed a fertilizer import program from 1995-1998. The imports were sold to NGOs and private sector distributors who served as the relay to move inputs through farmers' associations to farmers. End distribution of these imports was a mix of aid (free or below cost distribution by NGOs), cash sales, and barter trade (crops for fertilizer). There was a subsidy on EU fertilizer sales declining from 50% in 1995 to 20% in 1998. Although there was no official change in MINAGRI extension recommendations during this period, one notes a gradual shift from 17-17-17 to increased use of DAP and urea during the short EU period: sales for the 1996A season were 90% NPK while those for the 1999A season were only 42% NPK with urea accounting for another 42% and DAP for 16%(EU fertilizer program data base).[2] Although the EU was the principal fertilizer importer from 1995-1998,OCIR Thé, SORWATHE, and OCIR Café were also importing limited quantities for use on tea and coffee while FAO and IFAD were importing small amounts in conjunction with development and relief programs (Murekezi 2000).

Even with EU assistance, consumption remained low during the entire period, and aggregate

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[2] This apparent shift from NPK to DAP and urea was not the result of any intentional policy change promoted by EU personnel in Rwanda (personal communication, Houyoux).

national imports peaked in 1998 at 4780 tons. Annual EU imports ranged from 2000-3000 tons, but there were large carry-over stocks every year. The EU program also experienced problems with unpaid input credit, forcing a reduction in the share of inputs distributed on credit in 1998 and a complete halt to credit sales in 1999. EU imports stopped in 1998 but distribution of carry-over stocks continued into 1999 while responsibility for fertilizer imports and distribution was gradually transferred to the Rwandan private sector.

1.3. Current Period (1999-present): Privatizing and Liberalizing the Market

Imports exhibited a temporary decline in 1999 (<3000 tons total) with the principal actors being one private sector trading company (which has since gone out of business) and OCIR Thé (Murekezi 2000). There is good evidence, however, of fertilizer import growth in 2000. BNR records showed imports of approximately 6500 tons for 2000–an encouraging sign. At least seven firms were involved in these fertilizer imports during 2000 (personal communication, Nyirimana).

The GOR made three policy decisions in late 1999 and early 2000 believed to have contributed to this growth in private sector imports. In late 1999 a law was passed requiring MINAGRI approval for all free distribution of fertilizers. This law was in response to complaints by private traders that they could not compete effectively in the fertilizer market if there continued to be free or subsidized distribution of fertilizers by donors and NGOs. In May 2000 fertilizers were officially declared exempt from ICHA[3] (15%) and entry (5%) taxes making it possible for importers to market fertilizer at lower retail prices (high prices are thought to be one of the key constraints to fertilizer uptake at the farm level). Also in late 2000, the World Bank Agricultural and Rural Markets Development (ARMD) project provided a line of credit at subsidized interest rates (9% rather than the market rate of 16%) to fertilizer importers. This line of credit was just beginning to be used during the third quarter of 2000.

Data on the product composition of recent imports is sketchy, but imports funded with the ARMD project credit were predominantly NPK and urea (BNR report, October 2000). There is also evidence that some NGOs (ARDI, CSC Gitarama, INADES) were distributing DAP fertilizers in 1999 and 2000 (FAO fertilizer program).

2. PATTERNS OF FERTILIZER USE

Information on recent use of inorganic fertilizers, organic fertilizers, and complementary investments in anti-erosion barriers comes from a survey conducted during the 2000A season by the MINAGRI's *Division des Statistiques Agricoles* (DSA) and the Food Security Research Project (FSRP). These results are compared to results from pre-war surveys conducted by the

[3] ICHA is *impot sur le chiffre d'affaires*.

DSA. The survey examined input use during the 2000A season and also asked retrospective questions about fertilizer use from 1995-1999.

2.1. Fertilizer Use: 1995-1999

Survey results show that over the 1995-1999 period a total of 12% of farm households used inorganic fertilizer at least once. Based on recall of specific quantities of fertilizer used in 1998 and 1999, DSA estimated average annual consumption to have been 3504 tons (7008 tons for the two-year period).[4] More than half of these purchases were reported by farmers in Gisenyi where a substantial amount of fertilizer was applied to potatoes.

2.2. Fertilizer Use: 2000A

Overview. Five percent of farmers used inorganic fertilizers and/or lime on three percent of cultivated land during the 2000A season. These numbers are slightly lower than comparative numbers for 1991 (7% of farms and 5% of area), however, the standard deviations for both the pre- and post-war data sets are very large and there is no statistically significant difference in fertilizer use between the two periods. Although only 3% of total cultivated area is fertilized, the spread of coverage varies sharply by crop, with an estimated 29% of rice, 21% of potatoes, and 19% of vegetable areas being fertilized. Surprisingly, only 3% of coffee area is fertilized.

Although many countries in SubSaharan Africa follow a pattern of fertilizer adoption whereby the largest farms (which are frequently the wealthiest) adopt fertilizer more rapidly than the smaller farms, this pattern is not evident in Rwanda. Fertilizer users during the 2000A season represented the same share of farms (4-5%) regardless of farm size category. In other words, we do not find a concentration of fertilizer users among the larger farms or a concentration of non-users among the smaller farms.

TABLE 2. INPUT USE AND CONSERVATION INVESTMENTS: 1991A VS. 2000A

	% of farms using specified input		% cultivated area covered*	
Type of Input/Investment	1991 A	2000 A	1991 A	2000 A
Chemical fertilizers or lime	7	5	5	3
Organic inputs	95	69	70	59
Conservation investments	93	65	76	65

Source: Estimated from MINAGRI/DSA survey data.

*In order to make the comparisons with 1991 data, we counted the entire area of a block if an input was used on any parcel within the block; this results in some over-estimation of area actually covered.

[4] This estimate is approximately the same as the quantity of fertilizer imports reported in Table 1 for 1998-1999, a fact that increases our confidence in the survey data.

The use of anti-erosion barriers and organic fertilizers (primarily manure) appears to have declined dramatically from 1991 to 2000. The agronomic trial data upon which estimates of Rwandan fertilizer profitability are based include a basal dose of manure (generally 3-10 tons/ha.) and assume that land is protected from erosion (FAO 1995, Kelly and Murekezi 2000). A decline in the use of manure and anti-erosion investments could act as a major constraint to expansion of fertilizer uptake as it is likely to result in reduced yield response and profitability. Table 2 compares the data on pre- and post-war use of inorganic fertilizers, manure, and conservation investments. These sharp decreases in use of manure and conservation investments are not surprising given the loss of livestock during the war and the shortage of agricultural labor since the war. They do, however, signal the need for the GOR to promote programs to rebuild livestock numbers and stimulate investment in erosion control in conjunction with programs to promote the adoption of inorganic fertilizers. For example, only 50% of the area treated with inorganic fertilizers in 2000A was also treated with organic fertilizers. This varied substantially across prefectures. Fertilizer users in Kigali Rurale, Butaré, and Gikongoro complemented the inorganic fertilizers with organic supplements on 75% of the area to which inorganic fertilizers were applied while those in other prefecture did less well. In Gisenyi, where more than 50% of Rwanda's fertilizer was used, only 32% of the area fertilized received organic supplements.

Fertilizer Use by Prefecture and Crop. Although the 2000A survey data are not robust when disaggregated to the prefecture and crop levels, they are the only data now available on post war fertilizer use drawn from a randomly selected national sample. Consequently, we present the patterns revealed by this data base, recognizing that the picture presented could be improved if supplemented with more detailed information collected at the local level.[5]

Table 3 shows that 1947 tons of fertilizer were used during the 2000A season. Forty-two percent of fertilizer consumed nationally was used on Irish potatoes and 21% on coffee. No other single crop represented any more than 6% of national consumption. Gisenyi consumed more fertilizer than all other prefectures combined (i.e., 56% of total 2000A consumption). Irish potatoes accounted for 51% and coffee 28% of fertilizer consumed in Gisenyi. Byumba was the second most important prefecture, consuming 18% of 2000A fertilizer; 68% of Byumba's fertilizer was used on Irish potatoes and 19% on beans.

Looking across each prefecture to identify the crop getting the largest quantity of fertilizer reveals a definite pattern of farmers applying fertilizers primarily to the crops with the more reliable output markets: Irish potatoes in Byumba, Gisenyi and Ruhengeri; rice in Cyangugu and Kigali Rural; vegetables in Butaré; tea in Kibuye; and bananas in Gikongoro and Umutara. Food crops such as beans, tubers, and cereals are being fertilized in a few cases, but total fertilizer application to these food crops represents only 10% of 2000A fertilizer use. There are two prefectures, however, where use of fertilizer on beans is an important share of total fertilizer use (19% in both Butaré and Byumba).

[5] The 2000A sample size is 1584 households of which only 72 (4.5%) used fertilizer, consequently several of the estimates of prefecture or crop level fertilizer use are based on a single observation and none of the cells in Table 3 are based on more than 10 observations.

TABLE 3. FERTILIZER USED DURING 2000A SEASON

(Details in Kilograms and Marginal Totals in Tons)

Crops	Butare	Byumba	Cyangugu	Gikongoro	**Gisenyi**	Gitarama	Kibungo	Kibuye	Kigali R.	Ruhengeri	Umutara	Rwanda (Tons)	Rwanda Share
Beans	11284	64232	0	0	**0**	6390	0	0	0	0	0	82	0.04
Peas	0	0	0	4025	**0**	0	0	0	0	0	0	4	0.00
Peanuts	0	0	0	0	**0**	0	0	0	0	0	0	0	0.00
Soybeans	0	0	0	0	**0**	0	0	0	0	0	5511	6	0.00
Sorghum	0	0	0	0	**25418**	0	0	0	0	0	0	25	0.01
Maize	4236	4565	0	0	**0**	0	0	0	0	0	0	9	0.00
Wheat	0	0	0	0	**0**	0	0	0	0	0	0	0	0.00
Eleusine	0	0	0	0	**0**	0	0	0	0	0	0	0	0.00
Rice	0	0	118078	0	**0**	0	0	0	1229	0	0	119	0.06
Cassava	0	0	0	0	**0**	11888	0	0	0	0	0	12	0.01
Potato	**13541**	**232038**	**0**	**3655**	**563099**	**0**	**0**	**411**	**0**	**6276**	**0**	**819**	**0.42**
Sw. Potato	564	35036	1554	367	**9727**	0	0	0	0	0	857	48	0.02
Colocase	0	0	0	0	**0**	0	0	0	0	0	0	0	0.00
Yam	0	0	0	0	**0**	0	0	0	0	0	0	0	0.00
Vegetables	29583	435	0	604	**84727**	0	0	0	0	0	8267	124	0.06
Banana	0	408	0	24054	**0**	32933	0	0	1175	0	15493	74	0.04
Coffee	0	0	21195	0	**304873**	81315	185	0	0	0	857	408	0.21
Other food	0	0	0	0	**0**	8140	0	0	0	0	0	8	0.00
Tea/indust.	0	0	395	0	**33891**	0	0	6089 7	1229	0	0	96	0.05
Woodland	0	4596	0	0	**0**	0	0	0	0	0	0	5	0.00
Fallow	0	0	0	34502	**73517**	0	0	0	0	0	0	108	0.06
Totals (tons)	59	341	141	67	**1095**	141	0	61	4	6	31	**1947**	
Share	0.03	0.18	0.07	0.03	**0.56**	0.07	0.00	0.03	0.00	0.00	0.02		1.00

Source: Analysis of DSA/FSRP 2000A survey data.

Note: Results are weighted observations. Product composition was: 68% NPK, 17% urea, 7% lime, 5%DAP, and 2% other types of fertilizer.

Another aspect of fertilizer use patterns concerns the quantities used by individual farmers. Among the small group of farmers using fertilizer in 2000A, 36% used just 1 to 5 Kg and 70% used less than 25 Kg Only 11% of users applied large quantities exceeding 75 Kg In other words, the distribution of fertilizer quantities across users is skewed with a large number of small consumers and a small number of large consumers.

The preponderance of farms making small purchases does not necessarily mean low application rates per hectare because typical farm sizes in Rwanda are very small (54% < 0.5 hectares) as are the particular fields being fertilized. The average rate of application among farmers using fertilizer was 118 kg/ha with prefecture averages ranging from a low of 2 kg/ha in Kigali Rurale to a high of 269 kg/ha in Byumba. This effective rate of application is in sharp contrast to the average national rate of fertilizer use during 2000A which was only 6 kg./ha.

Information presented on current patterns of fertilizer use suggest that there is substantial potential for increasing fertilizer use by increasing adoption rates (currently only about 5% of farmers using fertilizer per year) as well as increasing the spread of fertilizer across cultivated land (currently about 3% of cultivated area but rising to approximately 20-30% of area for crops such as potatoes, vegetables, and rice that have good market potential). Given that farmers now using fertilizer are few in number and are using fertilizer at relatively high rates of application per hectare (118 kg/ha on average), there is much greater scope for increasing aggregate fertilizer consumption by increasing the number of adopters and the spread across cultivated land than by increasing application rates. Nevertheless, the relatively high application rate gives us confidence that farmers who are using fertilizer are finding it profitable; were it not profitable they would be unlikely to be using such high doses.

The fertilizer data presented above was collected during the 2000A season but includes information on fertilizer used during the 1999C season. The C season consists primarily of vegetable production in marsh lands. We do not yet have survey data for fertilizer consumption in the 2000B season, but there are some major differences in production patterns between the A and B seasons that should result in a slightly different pattern of fertilizer use for 2000B. For example: (1) sorghum is a very minor crop during season A but a major crop in season B, (2) potato production is of equal importance during seasons A and B in Gisenyi but much more important during season B in Ruhengeri, (3) maize production is more important in Season A than in Season B. In other words, a simple doubling of the 2000A fertilizer use patterns is unlikely to provide a good estimate of total annual fertilizer consumption because of changes in the relative importance of key fertilizer using crops. Once 2000B data has been analyzed we should have a full picture of fertilizer consumption during 2000.

3. POTENTIAL FOR INCREASED FERTILIZER CONSUMPTION

The current MINAGRI focus on increasing the adoption of improved inputs is predicated on the belief that current fertilizer consumption is well below levels that could be used profitably by Rwandan farmers. This brings us to review what is known about fertilizer response and profitability in Rwanda and how these factors shape agronomic and agro-economic potential as well as effective demand.

3.1. Review of Fertilizer Response Data and Updating of Profitability Analyses

In 1999, DSA/FSRP and FAO collaborated on a study to summarize what was known about fertilizer response in Rwanda and update fertilizer profitability analyses using post-war input and output prices and transportation costs. MINAGRI organized a workshop in December 1999 to discuss these research results and a final report, incorporating additional insights gained from the workshop, was published in February 2000 (Kelly and Murekezi). Although fertilizer response data is generally associated with one of the 18 agrobioclimatic (ABC) zones found in Rwanda, the authors made an effort to map the results of the profitability analyses on an administrative map of Rwanda which identifies the communes where there is potential for profitable fertilizer use on the 11 crops studied: climbing beans, maize, rice, sorghum, Irish potatoes, soybeans, sweet potatoes, peas, wheat, cassava, and cabbage.

Profitability was evaluated by calculating value cost (v/c) ratios, i.e., the value of additional production obtained from using fertilizer divided by the cost of the fertilizer treatment. A v/c ratio >2 is generally considered an adequate incentive for fertilizer adoption; it means that the financial returns to using fertilizer are two times greater than the cost.

A major finding of the report was that using a combination of DAP and urea was more profitable than using the NPK fertilizers (17-17-17) that had been recommended in the past. Although there was concern expressed at the workshop about future problems with potassium deficiencies (particularly for tuber crops) if the GOR adopted an official policy of recommending DAP and urea, there was general agreement that agricultural research had shown little response to potassium fertilizers in most ABC zones. To avoid future problems, monitoring soil nutrient levels was recommended for zones using large amounts of DAP and urea so that potassium could be reintroduced when deficient. Also emphasized by workshop participants was the need to combine inorganic fertilizers with adequate quantities of manure (in all zones) and lime (in zones with acid soils) if fertilizer efficiency and profitability were to be achieved and sustained.

Among the highlights of the fertilizer profitability findings were:

- Superb potential for fertilization of Irish potato (v/c ratios frequently >8) in about one-fourth of all communes.
- Excellent potential (v/c ratios frequently > 3) for DAP fertilizer used on climbing beans[6] in six ABC zones; these zones are found in approximately one-third of Rwanda’s communes;
- Excellent potential for sweet potatoes (v/c for DAP/urea combinations generally >3) in about one-fifth of communes;
- Good potential on sorghum (v/c ratios from 2-4) in 4 ABC zones representing about one-fourth of communes.
- Good potential (v/c ratios generally 2-3) for maize in five ABC zones represented in at least one-third of the communes;

For all of the above crops, it is possible that fertilizer could be used profitably in a wider range of zones and communes, but this cannot be determined without access to additional agronomic research on fertilizer response in these zones.[7]

Fertilizer use was found to be profitable on irrigated rice, horticultural crops such as cabbage and on inoculated soybeans in a limited number of ABC zones for which agronomic research results were found. More agronomic research results are needed to make recommendations for these crops over a wider range of ABC zones.

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[6] Fertilizer response is poor on traditional dwarf varieties of beans and not recommended.

[7] It is possible that some of this research has already been carried out (e.g., rice response outside of the Butaré area) but the documentation was not available at the time the Kelly and Murekezi study was conducted.

Fertilizer use on peas, cassava and wheat was clearly unprofitable and not recommended given prices prevailing during the 1995-1999 period.

The report and workshop did not deal with coffee and tea–export and industrial crops for which fertilizer imports and use tend to be managed by the industries themselves.

In sum, the updated profitability analyses confirmed that there is substantial potential for profitably increasing fertilizer use in Rwanda while simultaneously identifying some crop/zone combinations where fertilizer is not profitable and should be avoided.

3.2. Estimating Agronomic and Agro-Economic Potential for Fertilizer Use

Developing an understanding of fertilizer potential and demand can be broken into three components:

(1) Estimating the agronomic potential;
(2) Estimating the agro-economic potential;
(3) Estimating effective demand.

The first step of estimating the agronomic potential involves identifying the maximum amount of fertilizer that could be used if farmers applied fertilizer on all cultivated land up to the point where an additional kilogram of fertilizer would result in a reduction rather than an increase in yields. In estimating agronomic potential, profitability of fertilizer use is not a consideration.[8] In Rwanda there have been various attempts in the past to estimate what has been referred to as 'theoretical demand'. These estimates come close to what is implied by agronomic potential, but they are generally based on fertilizer doses at the point on the production function where marginal yields begin to decline rather than the point where total yield begins to decline (i.e., 'theoretical demand' is a more conservative estimate than agronomic potential).

Table 4 summarizes key characteristics of three estimates of 'theoretical demand' for Rwanda found in the literature. One such estimate, developed in 1987 and projected forward reported a 'theoretical demand' of 435,700 tons of fertilizer for the year 2000. Other analysts have reported estimates of about 65,000 tons for 1989 and 272,000 tons for 1992. A weaknesses in these estimates is that Rwanda has not conducted fertilizer trials and demonstrations for the full range of crop/zone combinations that farmers are cultivating; consequently, results from zones where trials have been conducted are assumed to be valid in zones where no research has been undertaken. This can lead to over- or under-estimates of fertilizer potential. In our opinion, estimating agronomic potential or 'theoretical demand' in the manner described above does little to contribute to our understanding of effective demand, which is really the most important estimate that needs to be made in a country attempting to build a private sector fertilizer market.

[8] This is equivalent to the point on the production function where the curve starts to decline (end of stage II).

TABLE 4. APPROXIMATIONS OF AGRONOMIC POTENTIAL FROM EARLIER STUDIES

Source	Theoretical Demand (tons)	Year	Cultivated Area (hectares)	Crops	Comments
CNA 1991	65,025 (53 kg/ha)	1989	1,216,200	Climbing beans, soybeans, barley, potatoes, sweet potatoes, tea, coffee	Fertilizer rates ranging from 100-400 kg/ha (64-175 kg/ha of nutrients).
CNA 1991	435,700 (284 kg/ha)	2000	1,529,193	Banana, all beans, peas, soybeans, groundnuts, maize, sorghum, wheat, rice, cassava, sweet potatoes, Irish potatoes, tea, coffee, and sugar	Projection based on 1987 cultivated area assumed to grow at 3%/year. Fertilizer rates ranging from 100-500 kg/ha.
Kayitare1997, citing FAO 1995	271,915 (232 kg/ha)	1992	1,169,200	Same food crops as above but no tea, coffee, or sugar	Fertilizer rates ranging from 100-400 kg/ha.

Estimating the agro-economic potential brings us a step closer to understanding the upper limits of effective demand. Agro-economic potential is determined by assuming that all land is cultivated using financially optimal fertilizer doses. Financially optimal fertilizer doses are determined by the point where the marginal returns to an additional kilogram of fertilizer are equal to the marginal cost of that fertilizer; this is also referred to as the profit maximizing point. Some analysts have made estimates of 'theoretical demand' for Rwanda that have been conditioned by economic considerations. The most common technique has been to estimate 'theoretical demand' for only those crops showing a v/c ratio >2 at the time of the analysis. One such estimate, using 1987 prices and projecting area cultivated and 'theoretical demand' to the year 2000, reported a 'theoretical demand' (roughly equivalent to agro-economic potential) of about 160,000 tons (CNA 1991).[9]

It is our opinion that if estimates of agro-economic potential are to provide useful information to policy makers and fertilizer importers, we need to employ stricter criteria than those used in the past to identify crop/zone combinations where there is agro-economic potential for fertilizer use. The recent updating of fertilizer profitability analyses provides a point of departure for building national estimates. Estimates completed to date are partial as they cover only seven crops: sorghum, maize,

[9] Using the v/c>2 criteria will produce an estimate of 'theoretical demand' that is lower than agro-economic potential as defined above (in the case of agro-economic potential the v/c would be 1).

Irish potatoes, soybeans, sweet potatoes, vegetables, and climbing beans.[10] Unlike earlier estimates of 'theoretical demand' that have assumed agronomic results from one ABC zone can be imputed to other ABC zones, we follow a strict rule of estimating agro-economic potential for only those crop/zone combinations that have direct evidence from within the zone that fertilizer use is profitable. The third important criteria is that our cut-off for profitability is a v/c ratio $\geq$ 3. This is a more conservative measure of profitability than the v/c ratio $\geq$2 used in Kelly and Murekezi to identify crop/zone combinations where fertilizer should be promoted. A ratio of 3 rather than 2 is selected here because it provides a margin of protection against changes in profitability associated with changes in prices that have taken place since the v/c ratios were estimated in 1999.[11] We assume that recommended doses of fertilizer will be applied to all land that is located in appropriate ABC zones and cultivated in these seven crops. Area cultivated by crop and zone was estimated by combining 2000A and 2000B survey data on cultivated areas with information from Berdinger (1993) on percent of land in each prefecture falling into each ABC zone.[12] Estimates thus far cover only 16% of total area cultivated during the 2000A and B seasons (Table 5). The poor coverage is due primarily to a lack of response data covering all the ABC zones where these crops are grown.

TABLE 5. CULTIVATED AREA COVERED BY ESTIMATES OF AGRO-ECONOMIC POTENTIAL FOR FERTILIZER

Crop	Total Hectares Cultivated	Hectares w. Fert. Potential	Fertilizer Potential Coverage
Beans	319,429	23,954	7%
Maize	89,395	2,633	3%
Sorghum	196,697	42,751	22%
Irish Potatoes	78,628	47,775	61%
Soybean	9,338	2,371	25%
Sweet Potatoes	189,988	21,693	11%
Vegetables	8,660	386	4%
Total	892,135	141,562	16%

Source: Calculated using DSA/FSRP 2000 A/B area estimates, Berdinger 1993 estimates of area in ABC zones, and Kelly/Murekezi 2000 v/c ratio estimates.

Table 6 shows our partial estimate of agro-economic potential based on the seven crops and 16% of cultivated area covered.. Neither the relative importance of the crops fertilized nor the ranking

[10] We also attempted to estimate potential for rice fertilizer but response data are available for only a small area in Butaré making it impossible for us to get a reasonable estimate because the 2000A and B survey data, collected to accurately estimate national production, do not provide accurate rice area data at the prefecture and zone level.

[11] See Table 7 below for input/output ratios reflecting relative changes in fertilizer and output prices.

[12] For example: Potato fertilizer is profitable in ABC zone 5c. In Gisenyi 21% of cultivable land is in zone 5c and there were 24,022 ha of cultivated potatoes grown in seasons 2000A and B. The area for which we estimate an agro-economic potential is total cultivated potato area * share of total area in zone 5c (24,022*.21=5,045 ha). This method is based on an implicit assumption that potato cultivation is distributed relatively equally throughout the prefecture. Given that most Rwandan farmers do not specialize, generally producing a mix of 3-5 crops during season A and 5-9 crops during season B, this is not an unreasonable assumption.

TABLE 6. AGRO-ECONOMIC POTENTIAL FOR BEANS, MAIZE, SORGHUM, IRISH POTATOES, SOYBEANS, SWEET POTATOES AND VEGETABLES													
(Metric Tons)													
Crop	Zones	Butare	Byumba-Umutara	Cyangugu	Gikongoro	Gisenyi	Gitarama	Kibungo	Kibuye	Kigali R.	Ruhengeri	Zone Total	Crop Total
Beans	1	0	0	103	0	0	0	0	0	0	0	103	2912
	4B	109	0	0	34	0	0	0	0	0	0	143	
	4C	55	0	0	0	0	815	0	0	80	0	950	
	4F	0	139	0	0	0	0	37	0	11	0	187	
	5C	0	0	0	0	410	175	8	0	0	936	1528	
Maize	2A	0	0	367	0	0	0	0	0	0	0	367	553
	2B	0	0	186	0	0	0	0	0	0	0	186	
Sorghum	4D	0	742	0	0	0	294	129	0	2155	144	3464	**7473**
	6A	0	0	0	0	0	0	1233	0	2776	0	4009	
Irish	2A	0	0	0	0	0	0	0	0	0	0	0	**7856**
Potatoes	2B	0	0	0	0	0	0	0	0	0	0	0	
	4C	45	0	0	0	0	0	0	0	29	0	74	
	5A	19	0	0	579	1764	0	112	422	0	84	2979	
	5B	0	477	0	7	20	0	1	559	38	1784	2887	
	5C	0	0	0	0	741	0	47	0	0	1127	1915	
Soybeans	2A	0	0	33	0	0	0	0	0	0	0	33	344
	4B	90	0	0	9	0	0	0	0	0	0	99	
	4C	45	0	0	0	0	104	0	0	3	0	152	
	4D	0	5	0	0	0	33	5	0	17	0	60	
Sweet	4B	1123	0	0	273	0	0	0	0	0	0	1396	3548
Potatoes	4D	0	293	0	0	0	550	127	0	1116	65	2152	
Veget*.	4B	99	0	0	13	0	0	0	0	0	0	112	112
Total Potential		1584	1657	689	916	2934	1972	1699	982	**6225**	**4140**	**22798**	

of prefectures by quantities of fertilizer reflect patterns exhibited in the 2000A survey data (Table 3). This can be expected to a certain degree given that Table 6 is an estimate for 2000A and B while Table 3 covers only 2000A. One of the more striking results in Table 6 is that the agro-economic potential for sorghum fertilizer appears to be as great as that for potatoes (7473 tons for the former and 7856 tons for the latter). Sweet potato fertilizer ranks third (3548 tons). In Table 3 there was very little application of fertilizers on both sorghum (1% of total use in 2000A–a season with little sorghum production) and sweet potatoes (2% of total use in 2000A). Although these crops should respond to fertilizer use in a profitable manner, our hypothesis is that Rwandan farmers, who are relatively new adopters, tend to fertilizer more commercial crops and also prefer to use fertilizer on the crops that have the highest potential for profitability (i.e., v/c ratios >8 such as those estimated for Irish potatoes). Once farmers have gained experience with the ‘starter crops,’ fertilizer use should spread to less profitable or less commercial crops. There was some evidence of this in Table 3 for Gisenyi where fertilizer was used in fairly large quantities on seven crops.

Another noticeable difference between 2000A consumption and agro-economic potential is that Gisenyi, which consumed more fertilizer than all other prefectures combined in 2000A, falls behind in terms of agro-economic potential. Kigali Rurale takes the lead with Ruhengeri second and Gisenyi third. It is the large increase in sorghum fertilizer that moves Kigali Rurale into the lead. For Ruhengeri, Irish potatoes make the difference.

Our desire is to improve this estimate of agro-economic potential as more data become available. The first step will be to add estimates of agro-economic potential for lime; this will be particularly important in regions of acid soils such as Gikongoro where fertilizer is not profitable without lime. Estimating the need for organic fertilizers (manure) will also be important as this will provide a basis for assessing whether the current supply of animals can produce the quantity of organic supplements needed to ensure profitable fertilizer response. The next step could be to add the principal export and industrial crops (coffee and tea) for which we need both agronomic response data and more precise area data. Rough estimates of agronomic potential for these crops and perhaps agro-economic potential may be available from OCIR Thé, and OCIR Café.[13] A final step will be extending the estimates to ABC zones for which we do not yet have good agronomic response data[14] For example, 2000A survey data shows that vegetables are being grown in all prefectures and that they are frequently fertilized, but we only have fertilizer response data permitting us to estimate agro-economic potential for vegetables grown in the low-lands of one ABC zone (*Plateau de Sud*). Rice presents a similar problem as does sorghum in Gisenyi (a prefecture currently using fertilizer on sorghum but for which we have no recommendations).

In sum, with this very partial estimate of agro-economic potential based on more conservative criteria than are commonly used for such estimates, our results show that (1) agro-economic potential is at least three times greater than current imports and utilization (22798 tons potential vs. 6-8000 tons imported in 2000) and (2) estimated cultivated area where fertilizer is known to be profitable is more than 5 times the area currently fertilized (16% of cultivated area showing potential vs. only 3% currently fertilized).

3.3. Effective Demand: Determinants and Estimates

Effective demand is the quantity of fertilizer that farmers would be willing to purchase if it were available. Estimating effective demand is the most challenging task, particularly in the Rwandan context where there has been very little fertilizer used in the past and most of that was distributed through government services or relief programs at subsidized rates. An understanding of the relative importance of various factors that influence fertilizer purchasing patterns contributes to our ability to design policies that will stimulate fertilizer demand.

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[13] Using figures of the 1999 OCIR Café census of coffee trees, we found the agronomic potential for coffee fertilization to be 20, 313 tonnes per year using NPK 20.10.10 or 12,188 tonnes per year using urea 46% plus manure and mulching. OCIR Thé estimates using 10,700 tonnes per year using the recommended fertilizer applications.

[14] Of concern here are all the grey and white areas of the maps in Kelly and Murekezi. It is possible that there are fertilizer response data from earlier research that were not found at the time of the Kelly and Murekezi study; if this is true, the process of expanding the recommendations will be more rapid if we find these studies than if new research is needed.

3.3.1. Determinants of Fertilizer Demand: Farmers' Views of Constraints

What do we mean by determinants of fertilizer demand. Determinants of effective demand can be divided into two broad groups: incentives and capacity. Incentives are primarily viewed as economic incentives that are summarized in indicators of fertilizer profitability such as the v/c ratios discussed above and determined by fertilizer response, fertilizer prices, and output prices. The updated fertilizer profitability analyses by Kelly and Murekezi showed that there were strong incentives (many v/c ratios >3) to use fertilizer in Rwanda for a broad range of crop/zone combinations. Even though there has been some deterioration in input/output price ratios in recent years (Table 7) due to increasing fertilizer prices and declining output prices, these changes have not been dramatic enough to result in unprofitable use for all crop/zone combinations reported in Kelly and Murekezi that had v/c ratios >3 in 1999. If profit incentives exist but farmers are not purchasing fertilizer it may be due to an inadequate supply of fertilizer or to a variety of capacity constraints.

Inadequate supply really means that the effective cost of fertilizer is much higher than the cost used in calculating v/c ratios. For example, if farmers cannot obtain fertilizer in their communities and must travel long distances to find it, the effective cost of fertilizer increases substantially; the cost becomes infinite if there are no supplies within feasible traveling distance. Inadequate supply reduces the incentives reflected by the v/c ratios as these estimates assume that fertilizer will be available.

TABLE 7. FERTILIZER INPUT/OUTPUT PRICE RATIOS FOR 1998 AND 2000 COMPARED

	1998		2000	
Fertilizer Price	Low	High	Low	High
	176 f/kg	200 f/kg	220 F/kg	250 F/kg
I/O Ratios				
Rice	0.7	0.8	1.0	1.1
Soybeans	0.7	0.8	1.4	1.6
Beans	1.0	1.2	2.2	2.5
Maize	1.4	1.6	2.6	3.0
Sorghum	1.27	1.4	2.7	3.0
Irish Pot.	1.8	2.0	6.0	6.8
Sw. Pot.	3.0	3.4	7.6	8.7
Cabbage	2.2	2.5	8.8	10.0

Source: Calculated from PASAR market price data.

Note: The i/o ratio is the number of kilograms of output needed to purchase one kilogram of fertilizer.

Capacity constraints can be subdivided into three groups: human capital, financial capital, and physical capital. For example, if farmers do not know about the economic incentives associated with fertilizer use, there is a human capital constraint that needs to be lifted by improving knowledge. If farmers do not purchase fertilizer because they don't have the financial capital, there is a need to build financial capital through savings and credit programs. If farmers do not purchase fertilizer because they don't have the physical capital to use it properly (anti-erosion investments, animals to provide complementary manure, farming tools and equipment, etc.) then this constraint needs to be addressed for agro-economic potential to be translated into effective demand.

There have not been any national studies of the determinants of fertilizer demand in Rwanda, but we do have some information from farm surveys that helps us better understand the factors that farmers take into account when making decisions about agricultural intensification. We summarize the key findings of these surveys below. One of the challenges in interpreting the results is resolving the apparently conflicting farmer opinions concerning the relative importance of different constraints and what the differences imply for the design of fertilizer promotion policies. We look forward to obtaining additional insights on these issues from conference participants, particularly those working directly with farmers.

Insights from the Birunga Maize Project Zone . A study conducted by Ngirumwami in 1989 as part of a maize promotion project in Birunga assessed farmers' attitudes about increasing maize production by adopting new varieties and fertilizers. The survey interviewed 138 farmers in the project zone, covering two communes in Gisenyi (Mutura and Rwerere) and two communes in Ruhengeri (Kinigi and Nkuli). The project area is one where maize is the principal food crop but Irish potatoes, beans and sorghum are also produced for home consumption by more than 50% of farmers.

Virtually all the farmers (97%) were already producing maize and all claimed they wanted to increase their maize production; but 59% were not willing to do this if it meant expanding maize area at the expense of some other crop (i.e., they were not willing to become more specialized in maize).[15] When asked what factors would stimulate them to use fertilizer on maize, 69% said they would need credit, 15% said they would only do it if fertilizer prices were more favorable, and 14% wanted guaranteed output prices. Note that the most frequently cited stimulus–credit–concerns improved access rather than improved incentives. The 29% mentioning price factors, were still concerned about whether the incentives were adequate.

Among the farmers interviewed, only 28% were marketing some of their current maize production; all others were producing entirely for home consumption. Sales were being made primarily to small assemblers (57% of transactions) and other producers (38%). When asked what they would do with additional production, only 19% claimed they would continue to use everything produced for home consumption; 22% said they would market all increased production and 59% said that increased production would go to both sales and home consumption. Some concern was expressed about an increase in Rwandan production being able to compete with imports that were coming from Zaire and Uganda. Half the respondents thought that imported maize was selling at lower prices than local maize while 31% thought it was selling at higher prices.

[15] This finding is particularly important given that there is a great deal of interest in promoting crop specialization in Rwanda to take the comparative advantage of different ABC zones into account.

TABLE 8. REASONS WHY FARMERS DID NOT USE FERTILIZER FROM 1995 THROUGH 1999

	Butare	Byumba	Cyangugu	Gikongoro	Gisenyi	Gitarama	Kibungo	Kibuye	Kigali	Ruhengeri	Umutara	Rwanda
	(percent of non-users)											
Don't know	41	22	78	50	56	84	76	39	27	60	41	53
High price	44	38	13	24	24	9	10	52	70	24	2	30
No credit	1	3	7	0	4	0	0	1	1	12	1	3
Not available	10	40	11	21	19	10	4	0	3	3	45	13
Other	5	31	2	6	2	1	10	8	0	1	18	7

Source: Source: MINAGRI/DSA survey data, 2000.
Notes: Percents are based on responses made by the 88% of farmers not using fertilizer from 1995-1999. Some columns total to more than 100% because multiple responses were permitted.

Insights from the 2000A DSA/FSRP survey. DSA/FSRP asked the 88% of farmers who did not use fertilizer from 1995 through 1999 to explain their reasons for not using it. The results are summarized in Table 8 which shows the breakdown of responses by prefecture. Many of the opinions expressed by randomly selected farmers in the DSA/FSRP sample differ from those in the maize survey discussed above, which focussed on farmers in a project zone that had benefited from targeted extension efforts.

Lack of Knowledge Inhibits Fertilizer Use. The most common explanation for non-use (53% of the 88% who were non-users, which represents 47% of all farm households) was that they did not "know" fertilizer. We interpret this response to mean that although they have heard about inorganic fertilizers, their knowledge of the benefits and of how to use the fertilizers was not strong enough to stimulate use. This response was more common in the prefectures of Gitarama, Cyangugu, Kibungo, and Ruhengeri than elsewhere.

Farmers also were asked if they thought that inorganic fertilizers needed to be used with complementary inputs to be effective–another way of assessing farmers' knowledge about fertilizers. The replies indicate that knowledge concerning the complementarity of organic and inorganic fertilizers is fairly strong (68% of respondents indicated that these inputs needed to be used together), followed by knowledge about pesticide use (46% reporting complementarities) and improved seeds (mentioned by 35% of respondents). Complementarities involving fungicides (27%) and compost (22%) were also mentioned. There were differences in the level of response across prefectures that suggest not only differences in the level of knowledge but also differences in needs due to soil characteristics. For example, more than 90% of respondents in Gisenyi and Gitarama recognized the need to combine inorganic and organic fertilizers while the highest mention of the need for lime (31%) came from farmers in Gikongoro, a zone of unusually acid soils. These results suggest that farmers are not as poorly informed about fertilizer use as the results reported in the previous paragraph suggest. Nevertheless, if the goal is to rapidly expand fertilizer use, all potential users need to understand the importance of using fertilizers in combination with key complementary inputs to ensure profitable results.

High Fertilizer Prices Are A Constraint. The next most common explanation for non-use from 1995-1999 was that fertilizer prices were too high (30% of the non-users or 25% of all farms). Typical farm gate fertilizer prices for the 1995-1999 period were in the 200-260 RwF/kg. range after the subsidy was removed in 1999 and in the 125-200 RwF/kg. range with subsidies. Prices varied by type of fertilizer and transportation costs, which differed across prefectures. High price was mentioned most frequently in Kigali Rural, followed by Kibuye, Butaré, and Byumba.

The 2000A survey asked farmers to provide an estimate of the maximum fertilizer price they would be willing to pay per kilogram for use on selected crops. Table 9 shows that average willingness to pay varied from 131 RwF/kg. for sorghum (a crop rated relatively low by farmers with respect to fertilizer yield response) to 161 RwF/kg. for coffee and vegetables (crops thought to exhibit strong yield responses); these prices are all substantially below those prevailing during the 2000A season (220-250 RwF/kg.) but the variation in willingness to pay across crops suggests that farmers do have better knowledge of fertilizer response and profitability by crop than suggested by the high number of farmers claiming that they 'don't know fertilizer'.

In most cases, the price of fertilizer alone is a poor indicator of the financial incentive to use the product because fertilizer profitability varies with changes in both the price of fertilizer and changes in the value of the supplemental production attributable to fertilizer use. Because such a small percent of Rwanda's farmers market their production, it is understandable that many currently look at the price of fertilizer in isolation rather than in conjunction with output prices. Nevertheless, as farmers begin the transition from semi-subsistence production to commercial agriculture, they will begin to pay more attention to input/output price ratios and ultimately make their own calculations of v/c ratios. If both of these ratios become more favourable, effective demand for fertilizer will grow.

Inadequate Fertilizer Supply Reduces Access for a Small Group of Farmers. Poor fertilizer supply was mentioned as a constraint by 13% of non-users (11% of all farms). The problem of supply was noted more frequently in Byumba (40% of non-users) and Umutara (45% of non-users). Supply seems to be less of a problem in Kibuye, Kigali Rural, Ruhengeri, and Kibungo where it was cited as a constraint by <5% of non-users (lack of knowledge and prices being more important).

TABLE 9. PRICES FARMERS ARE WILLING TO PAY FOR FERTILIZER

	Prices Farmers are Willing to pay for Fertilizer (RwF/kg)	
Crop	National Average	Standard Deviation
Beans	141	77
Potatoes	144	71
Vegetables	161	78
Coffee	161	66
Sorghum	131	77

Source: DSA/FSRP Survey Data 2000A.

Credit Constraints Seldom Mentioned. Lack of credit was mentioned by a small group of non-users (3%, equivalent to 2.6% of all farms), representing a minor factor in the aggregate picture where lack of knowledge, high prices, and supply factors predominate. We note that these results differ substantially from those of farmers in the maize project zone where knowledge of fertilizer was no doubt increased by project activities and many farmers (69%) had arrived at the stage of wanting fertilizer but not having the cash flow to purchase it.

Results from a survey of coffee farmers. With coffee being a commercial crop, one would expect to see a high incidence of its fertilization but this is not the case at present in Rwanda. A survey conducted by OCIR café in 1999 found that only 4.7% of coffee farmers used fertilizers. The main reasons cited by the farmers for their non-use of fertilizers was the high cost of fertilizers (52.4% of the farmers), unavailability of fertilizers in the region (47.2%), and inadequate knowledge of fertilizers (23.9%). Complaints about the high costs suggests a need to update fertilizer profitability analyses for coffee (an important gap in the Kelly and Murekezi work).

In sum, the perceived constraint varies depending on the knowledge and experience of farmers. On an aggregate national scale, lack of knowledge appears most important (DSA/FSRP survey results). Although farmers have general notions about fertilizer and how to use it they appear to feel that their knowledge is not sufficient to take the risk of purchasing fertilizer. We believe that references to prices being too high are also related to lack of knowledge–farmers are simply not aware of the numerous opportunities for profitable fertilizer use at prevailing input/output prices. Among farmers with better knowledge of fertilizer (e.g., those in the maize project zone or coffee producers), credit and supply issues become important.

3.3.2. A Partial Estimate of Effective Demand

As noted above, we do not have adequate data on past fertilizer consumption patterns to accurately estimate effective demand for fertilizer. We have, however, developed a set of assumptions about how farmers are likely to respond to crops with different levels of predicted profitability and used these assumptions to see if we can estimate a demand for crop/zone combinations covered by the Kelly and Murekezi analysis. As noted earlier, this is a very partial estimate of effective demand because it does not attempt to estimate demand for crop/zone combinations where there is no direct evidence of fertilizer response and profitability (i.e., primarily the grey and white area of the maps in Kelly and Murekezi). In effect, our estimate can be considered a minimum effective demand for 16% of cultivated area, given prevailing prices and farmers' knowledge of fertilizer. The key assumptions used in the estimate are that:

(1) Farmers will fertilizer all land planted in maize, sorghum, beans, Irish potatoes, soybeans, vegetables and sweet potatoes that is located in the ABC zones where the estimated v/c ratio is $\geq$3;

(2) The dose used will be less than the recommended dose:
if v/c ratios are 3-4.9 the dose will be 10% of recommendations;
if v/c ratios 5-9.9 the dose will be 30% of recommendations;
if v/c ratios are $\geq$10, the dose will be 75% of recommendations.

The logic underlying these new assumptions is that the greater the potential returns to fertilizer use the greater the demand by farmers who are just learning to use fertilizer.[16] Using these assumptions we obtain a partial effective demand of 7,941 tons/year for the seven crops covered in the analysis (Table 10). The amount is one that seems reasonable in the current Rwandan context, and the estimates by crop and prefecture better reflect current consumption patterns than the estimate of agro-economic potential reported in Table 6. Interestingly, Ruhengeri now comes out as the leader due to use of fertilizer on potatoes. Kigali Rurale falls behind both Gisenyi and Ruhengeri because most of the potential sorghum area has v/c ratios <5. This is a very rough and partial estimate of effective demand based on some very simple assumptions. It is presented

TABLE 10. ESTIMATED FERTILIZER DEMAND FOR BEANS, MAIZE, SORGHUM, IRISH POTATOES, SOYBEANS, SWEET POTATOES AND VEGETABLES

(Metric Tons)

Crop	Zone	Butare	Byumba-Umutare	Cyangugu	Gikongoro	Gisenyi	Gitarama	Kibungo	Kibuye	Kigali R.	Ruhengeri	Zone Total	Crop Total
Beans	1	0	0	10	0	0	0	0	0	0	0	10	357
	4B	33	0	0	10	0	0	0	0	0	0	43	
	4C	5	0	0	0	0	82	0	0	8	0	95	
	4F	0	42	0	0	0	0	11	0	3	0	56	
	5C	0	0	0	0	41	17	1	0	0	94	153	
Maize	2A	0	0	37	0	0	0	0	0	0	0	37	55
	2B	0	0	19	0	0	0	0	0	0	0	19	
Sorghum	4D	0	74	0	0	0	29	13	0	216	14	346	
	6A	0	0	0	0	0	0	123	0	278	0	401	747
Irish	2A	0	0	0	0	0	0	0	0	0	0	0	
Potatoes	2B	0	0	0	0	0	0	0	0	0	0	0	
	4C	14	0	0	0	0	0	0	0	9	0	22	
	5A	14	0	0	434	1323	0	84	317	0	63	2235	
	5B	0	358	0	6	15	0	1	420	28	1338	2165	
	5C	0	0	0	0	555	0	35	0	0	845	1436	**5858**
Soybean	2A	0	0	3	0	0	0	0	0	0	0	3	
	4B	9	0	0	1	0	0	0	0	0	0	10	
	4C	14	0	0	0	0	31	0	0	0	1	46	
	4D	0	3	0	0	0	25	4	0	13	0	45	104
Sweet	4B	112	0	0	27	0	0	0	0	0	0	140	
Potatoes	4D	0	88	0	0	0	165	38	0	335	20	646	785
Veget.*	4B	30	0	0	4	0	0	0	0	0	0	34	34
Est.Demand		230	566	69	483	**1934**	349	310	736	890	**2374**	**7941**	

Source: Estimated by authors (see text for details)
Notes: Estimates assume that all land cultivated in crop/zone combinations known to have v/c ratios >3 receive following shares of recommended doses:v/c ratios 3-4.9 receive 10% of dose; v/c ratios 5-9.9% receive 30%; v/c ratios =>10% receive 75% of recommended dose.
* Cultivated area for vegetables available from 2000A/B data does not fall in ABC zones for which we have agro-economic analyses indicating that these crops can use fertilizer profitably. The agro-economic potential for vegetables is very likely much greater than what is estimated here, but we need response data for ABC zones where the crops are currently being cultivated to be sure that fertilizer use would be profitable.

[16] These assumptions produce the same results as assuming that only 10%, 30%, and 75% of the land cultivated in these crops would be fertilized.

as a point of departure for discussions on the amount of fertilizer that could be absorbed by Rwandan farmers given current prices and farmers' knowledge of fertilizer. If farmers now using fertilizer on these five crops realize good profits, fertilizer demand could grow rapidly, first arriving at the estimated level of agro-economic potential for these crops (22798 tons annually) and then surpassing it as researchers as well as farmers working on their own identify new crop/zone combinations where fertilizer can be used profitably.

3.3.3. Converting Potential to Effective Demand.

The short-run challenge is figuring out how to rapidly turn agro-economic potential into effective demand. Given the very low levels of adoption (about 5% of farmers), very low spread (3% of land receiving fertilizer), and the very low fertilizer application rates (4 kg/hectare on average), relatively small increases in total adoption and spread could result in doubling and tripling fertilizer consumption. For example, moving from 5 to 10% adoption, if new adopters used about the same quantities of fertilizer as current adopters, could double season A consumption from the approximately 2000 tons used in 2000A to 4000 tons for a single season. As noted above, it appears unlikely that efforts to increase the rate of application currently used by farmers will have much effect on increasing aggregate fertilizer consumption.

At present, the most logical approach for promoting fertilizer seems to be to increase the rate of adoption. Thus far we have two clues drawn from current fertilizer consumption patterns and farmers' opinions that suggest ways of targeting programs to increase adoption rates:

- Fertilizer use is greater on crops with higher v/c ratios and/or dependable markets;
- Fertilizer use could be increased in selected areas by reducing the supply constraint

The supply constraint appears to be most important for coffee farmers and in the prefectures of Umutara and Byumba.

Another clue we have concerning means to increase the spread of fertilizer (i.e., area covered) comes from the maize survey:

- 69% of farmers in a maize intensification project zone identified credit as a constraint to intensifying production.

This suggests that once farmers become aware of the yield increasing potential of fertilizers through exposure to targeted extension programs, fertilizer credit is cited more frequently as a constraint than by farmers such as those in the DSA 2000A survey who are randomly selected and unlikely to have as good knowledge of fertilizer potential. The latter group tends to indicate that lack of knowledge or price is the constraint, seldom mentioning credit.

Increasing adoption among farmers who report lack of knowledge and/or prices as constraints can be addressed by improvements in extension efforts. The issue of developing effective extension services in Rwanda is too broad and too controversial to be adequately addressed here, but it is clear that the extremely limited MINAGRI budget (approximately 2% of the national budget in 1999) during the past several years has made it very difficult for extension personnel to interact directly with a large number of farmers.[17]

The farmer training program pursued by the MINAGRI during the past two years has informed model farmers about fertilizers as well as other techniques of agricultural intensification. Thus far the program has provided approximately 4500 farmers (30 per commune) with classroom training. The second phase of the training program is a series of on-farm fertilizer demonstration plots (to begin in the 2000B season) that will permit farmers who have received the classroom training to practice what they have learned about fertilizers and demonstrate the results to others in their communities. The effectiveness of these training programs and demonstration plots needs to be carefully monitored (and adjusted, if necessary) to ensure that farmers are getting increased yields and incomes from the use of fertilizer and that after participation in the training and demonstration plot programs farmers' demand for improved techniques and inputs, particularly inorganic fertilizers, grows. It is believed that once non-users have seen demonstration plots with superior yields, they will gain the confidence needed to try fertilizer for themselves.

Extension needs to work with NGOs and fertilizer retailers to significantly increase the number of fertilizer demonstrations taking place and to ensure that the demonstrations are well monitored. This means demonstration farmers are well-trained and supervised and that data are collected permitting analysis of yields, profitability, and impacts on soil nutrient content.

Given the Kelly and Murekezi profitability results, it is clear that fertilizer price is more of a knowledge problem (i.e., lack of knowledge about potential profitability) than a price problem. Nevertheless, improvements in input/output price ratios will stimulate adoption. It is generally more desirable to accomplish this through reductions in the price of fertilizer than through increases in the output price, particularly when the output is a food product in high demand by food-insecure households. Reductions in fertilizer prices tend to come about through increases in the quantity of fertilizer demanded (which permits suppliers to realize economies of scale) and when fertilizer markets become more competitive (as this drives down the margins of various actors in the input supply chain).

[17] For example, the issue of which institutions (e.g., fertilizer distributors, government, NGOs, primary and secondary school programs, etc.) should provide what types of extension services (e.g. theoretical training, on-farm demonstrations, monitoring and evaluation, etc.) needs to be resolved, taking into account the strengths and weakness of all potential participants (e.g., human resources, financial resources, willingness to collaborate in a joint effort with others, etc.).

4. CONCLUSIONS

4.1. Fertilizer Potential

- The potential for profitable fertilizer use in Rwanda during the next few years is high;
- Conservative estimates covering only 16% of cultivated area suggest current potential for a minimum of 22798 tons per year;
- There is an urgent need to evaluate fertilizer response and profitability for crop/zone combinations not covered by the present analyses so that estimates of agro-economic potential can be made for the remaining 84% of cultivated area.

4.2. Converting Potential to Effective Demand

- The most rapid way of ensuring that the fertilizer potential already identified is realized will be to increase the rate of adoption (vs. the spread or the rate of application);
- The more rapidly the rate of adoption increases the faster aggregate demand and imports will increase, thereby promoting lower fertilizer prices through economies of scale and increased competition;
- Improving farmers' knowledge of fertilizer potential and how to use the input appears to be the best way to reach the large share (53%) of non-users who claim they 'do not know fertilizer';
- Non-adopters in zones where fertilizer is already used and available (i.e., the northwest) should be targeted first as it will promote more rapid growth in adoption than no targeting or targeting farmers in zones with little fertilizer experience and poor supply;
- Efforts to improve farmers knowledge must be accompanied by efforts to make sure there is fertilizer supply available where training is taking place;
- Improving supply for farmers who already want fertilizer but can't find it could increase fertilizer consumption among some coffee producers as well as farmers in Byumba and Umutara who complained of supply problems;
- Development of an input credit program is **not** recommended in the short run because (1) the need for credit becomes more critical once adoption has taken place and (2) developing a credit program in Rwanda, where there is no history of one, is likely to be more time consuming and costly than increasing fertilizer demand through growth in the number of adopters.

4.3. General Policy and Research Issues

- MINAGRI and its development partners (donors, NGOs, fertilizer suppliers, etc.) need to figure out how to develop an efficient and effective extension program which includes a good monitoring component (who will do what and where);

- MINAGRI should evaluate the pros and cons of moving toward an official policy of promoting DAP and urea in lieu of NPK (it is unofficially moving in this direction via demonstration trials);
- A research program needs to be developed to address the gaps in knowledge about fertilizer response and profitability; this program should develop systematic criteria for evaluating profitability and determining the extent to which results from some zones can be applied to others; GOR needs to decide who will do what and how it will be funded;
- Some focussed studies in zones where fertilizer is already consumed in large quantities should be considered in an effort to learn from these successes (i.e., is it the crop that is driving everything or are there other factors related to farmer characteristics, fertilizer access, etc.).

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