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**REPUBLIC OF RWANDA
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FERTILIZER RESPONSE AND PROFITABILITY IN RWANDA

A Synthesis of Findings from MINAGRI Studies Conducted by

The Food Security Research Project (FSRP)

and

The FAO Soil Fertility Initiative

By

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February 2000

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FERTILIZER RESPONSE AND PROFITABILITY IN RWANDA

A SYNTHESIS OF FINDINGS FROM MINAGRI STUDIES CONDUCTED BY THE FOOD SECURITY RESEARCH PROJECT AND THE FAO SOIL FERTILITY INITIATIVE

1. INTRODUCTION

1.1 Policy Context

The Government of Rwanda (GOR) has proposed the following actions and policies aimed at enhancing the use of improved farm inputs:¹

- ? Identify the potential for fertilizer use by agro-ecological zones (the most fertilizer responsive crops and varieties and the most effective types of fertilizer for each zone).
- ? Promote an increased supply (imports) of fertilizer progressively from the current annual average of 4,000 tons to 10,000 tons within five years.
- ? Reinforce farmers' technical capacity to use fertilizers through extension programs.
- ? Reinforce farmers' interest in and access to fertilizers (by improving the credit system, improving markets for high value crops, etc.).
- ? Create an environment which encourages private sector fertilizer marketing (importation, distribution, etc.) through the reduction of import and sales taxes and improvement in the physical infrastructure (roads, stores, etc.) to make the business profitable.

Knowing what fertilizers to recommend for different crops and zones as well as having a good grasp of the farm-level profitability of fertilizer given various input/output price scenarios is a critical first step in implementing the entire program. Consequently, a key objective of the Food Security Research Project (FSRP) and the FAO Soil Fertility Initiative (SFI) has been to update analyses of fertilizer profitability using existing sources of fertilizer response data and recent prices for fertilizer and key crops.

1.2. Objectives of the Synthesis

The objectives of this synthesis are to:

- Present in synthesis form key conclusions and recommendations of the FSRP/FAO-SFI studies on fertilizer profitability in Rwanda;
- Incorporate into the synthesis information and comments obtained from participants in the December 15, 1999, MINAGRI Fertilizer Profitability Workshop conducted to present and validate the preliminary findings of the two studies.

¹Ministry of Agriculture, Animal Resources and Forestry. 1999. *Proposed Fertilizer Policy*.

1.3. Conceptualising Potential and Effective Fertilizer Demand

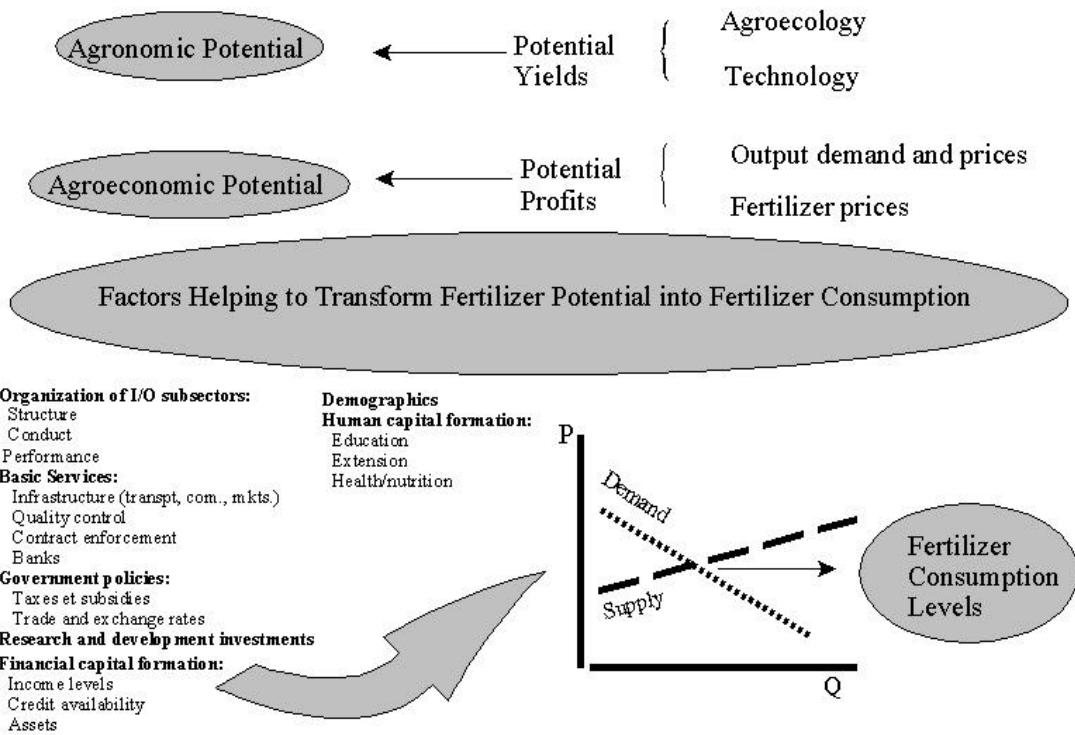
Before presenting the results of the FSRP/FAO-SFI fertilizer profitability studies, it is helpful to identify the factors that affect fertilizer profitability and understand how fertilizer profitability analyses fit into the larger picture of fertilizer subsector development activities.

Figure 1 is a schematic diagram of various factors affecting levels of fertilizer consumed. The upper half of the diagram deals with what we refer to as the ‘agronomic’ and ‘agroeconomic’ potential for fertilizer. Agronomic potential is a function of the physical response of a plant to an application of fertilizer in a given environment (soils, climate, etc.) - it is the technology interacting with the plant and its environment to produce a given yield response. A given technology may have very strong agronomic potential (i.e., high yield response) but still not have good ‘agroeconomic’ potential. Agroeconomic potential is a function of the yield response plus the influence of input and output prices – input prices must be relatively low and output prices relatively high for a particular fertilizer technology to have good ‘agroeconomic’ potential. In brief, the greater the yield response, the lower the input prices, and the higher the output prices, the greater the potential will be for strong fertilizer demand.

Yield response, input prices, and output prices, however, are not free standing, independent factors that determine fertilizer demand but rather the net result of a complex set of interactions that are influenced by government policies and investment decisions, consumer demand for food and fibre, as well as independent decisions made by farmers and entrepreneurs active in input and output markets. The lower half of Figure 1 lists a few of the many factors that can influence fertilizer demand by acting on input or output prices or the efficiency with which inputs and outputs are marketed. The point of the diagram is to note that even strong agroeconomic potential is not a guarantee of strong fertilizer demand if there are serious inadequacies or uncertainties in the marketing systems (e.g., late delivery of fertilizers, questions about quality, highly volatile output prices, etc.).

This paper on fertilizer response and profitability in Rwanda focuses on the upper half of Figure 1 dealing with the agronomic and agroeconomic potential for fertilizer demand. Identifying the crops and zones for which this potential is strong is an essential first step in the development of Rwanda’s fertilizer sub sector. We review current knowledge of fertilizer response and examine the extent to which that response, when subject to prevailing fertilizer/output price ratios, is likely to be profitable for Rwandan farmers. Section 2 discusses methods used in the profitability analyses and Section 3 presents the results. The paper concludes in Section 4 with a discussion of the implications of the profitability study results and makes recommendations for different options that the government and private sector might consider for turning the agroeconomic potential identified into effective farm-level fertilizer demand.

Figure 1: Factors Affecting Fertilizer Consumption Levels



Source: Naseem and Kelly. 1999.

2. BACKGROUND ON THE STUDIES AND RESEARCH METHODS

2.1. Criteria Used to Evaluate Profitability

Both the FSRP and the FAO/SFI studies use estimated value/cost ratios to evaluate the potential profitability of fertilizer. The value/cost ratio is calculated as:

$$\text{VAP/CFT}$$

where VAP = the value of additional production attributable to the fertilizer treatment
CFT = the cost of the fertilizer treatment

In classifying treatments as ‘profitable’ at the farm level both studies used a $v/c \geq 2$ as the cut-off point. In other words, the minimum incentive required for a farmer to use fertilizer is the case where the potential returns to the investment are at least double the cost of the investment. This is a common rule of thumb used in fertilizer analysis for agricultural systems where farmers are just beginning to adopt fertilizer. Although strictly speaking, a $v/c > 1$ is profitable (costs of the investment are covered and there is something left over for profit), farmers who have limited financial resources and face substantial production and price risks (high inter-annual variability in yields due to climatic factors and high variability in prices due to poorly developed markets) are seldom willing to risk an investment unless estimated returns are substantially greater than the investment. There is no debate in the literature that the v/c must be at least 2. There is, however, substantial debate as to whether the ratio must be at least 3 in many areas of Africa. The opinion of the authors is that cases where the v/c ratio is 3 or better are the cases where fertilizer promotion is most likely to succeed in the short-run. Cases where the v/c is only 2 or slightly higher, are potentially profitable, but will require more extension assistance and monitoring to ensure that farmers are using fertilizer properly and able to obtain the yields achieved during the earlier trials and demonstrations providing the fertilizer response data used in this report.

Although both the FSRP and the FAO/SFI reports used the same profitability criteria, there are numerous differences in the sources and nature of the response data as well as the input and output price assumptions used. These differences are described in the next two sections.

2.2. Summary of FSRP and FAO/SFI Methods

The FSRP approach has been to:

- (1) Review and synthesize published documents reporting results of past fertilizer trials and demonstrations for five key crops: climbing beans, maize, rice, sorghum, and potatoes; given the variety of sources consulted, FSRP response data examined varies considerably in terms of numbers of observations, sites and years covered, and treatments evaluated (including some information on response to manure and lime applications);

- (2) Use the 1995-1999 market price data collected by the PASAR² to develop a set of hypotheses about output prices faced by farmers (price variations across years, seasons and markets are taken into account after converting data to real prices using December 1998 as the base year); prices for each analysis were selected from markets identified as the ones most frequently used for a particular crop by farmers in a particular agrobioclimatic zone;
- (3) Calculate the cost of various types of fertilizer by prefecture (based on fertilizer prices for Kigali supplied by potential importers in early 1999 and transport costs provided by both fertilizer distributors and the World Food Program);
- (4) Estimate the probable financial returns (v/c ratio) to the use of fertilizer for selected crop/zone combinations by combining information from the first 3 steps;
- (5) Prepare a preliminary report of findings that included an evaluation of the relative strength of the different v/c ratios estimated (e.g., giving more weight to examples with a large number of sites, years, or repetitions covered in the trials or demonstrations); and
- (6) Develop an interactive spreadsheet that permits analysts to change/update assumptions about crop response to fertilizer, fertilizer prices, transport prices, and output prices.

The SFI/FAO approach has been to:

- (1) Use NP (nitrogen/phosphorous) response data to estimate fertilizer production functions for the five key crops noted above plus soybeans, peas, wheat, sweet potato, cassava, and cabbage. The number of observations, agrobioclimatic zones covered, and dates for the response data vary by crop, but all data were collected as part of the FAO/DANIDA Project which was active throughout the 1980s and early 1990s. All trials were conducted on farmers' fields using a basal dose of K (34 kg for pulses, 42 for cereals, and 50 for tubers) and an application of manure that represented farmers' usual practices.
- (2) The quadratic model was then used to identify the dose of N and P that would result in a minimum marginal rate of return of 2 (equivalent to a v/c ratio ≥ 2 and referred to as the *economically optimum dose*),³ using prices for N and P based on a weighted average of nutrient prices represented in the three fertilizers currently available in Rwanda (NPK, DAP, and urea).
- (3) V/C ratios were then calculated using two scenarios about the fertilizer products used to supply the *economically optimum dose* : The quantity of NPK (17-17-17) and urea required versus the quantities of DAP and urea required.
- (4) Fertilizer costs were based on prices for fertilizer 1999 imports; the prices reflect a policy of pan-territorial pricing as the private sector importer/distributor (Business Center) added a fixed transport cost to all fertilizer delivered throughout the country regardless of distance and actual cost.
- (5) Output prices were the September/October 1999 nominal prices reported by PASAR (for most crops this is the period of the year when prices are low); prices for each analysis were taken from the most active markets for the particular crop/zone combination being examined.

² Projet d'Appui à la Sécurité Alimentaire au Rwanda

³ Note that the economically optimum dose is NOT the profit maximizing dose, which has a marginal rate of return equal to one. The logic in making this distinction is based on a belief that the profit maximizing dose is too expensive and too risky to be considered during the early stages of fertilizer promotion in Africa.

(6) SFI/FAO has developed a set of spreadsheets (EXCEL 97) that can be used to evaluate how changes in fertilizer prices or output prices would affect fertilizer recommendations.

Table 1 summarizes the key methodological differences between the two studies.

Table 1. Comparison of Analytical Methods Used In FSRP/FAO-SFI Fertilizer Studies

Methods	FAO	FSRP	Impacts on V/C ratio
Fertilizer prices	1999 actual price (RwF/kg) DAP 218 Urea 211 NPK 209 (includes transport to rural areas)	1999 estimated price ranges (RwF/kg) DAP 226-260 Urea 175-225 NPK 207-226 (transport 3-12.5 RwF/kg additional depending on location)	V/C FAO generally > V/C FSRP
Output prices	·Sep/Oct 1999 nominal prices ·One scenario	·Average real monthly prices for 1995-1999 ·Two scenario	V/C FSRP generally > V/C FAO
Response data	·N/P fertilizer trial data ·Production functions ·Manure/lime not valued ·No analysis of K.	·Secondary data ·No modeling ·Manure & lime valued ·N,P, and K covered.	Two approaches complementary giving GOR broader range of results/options

2.3. Implications of Differences in the FSRP and FAO/SFI Methods

2.3.1. Response Data

Overall, the two studies are extremely complementary with respect to response data used, providing much broader coverage of both fertilizer treatments and zones than was accomplished by the individual studies. Nevertheless, it is useful to point out some of the strengths and weakness of the different sources of response data used.

The potassium (K) issue. The strength of the response data used by FAO/SFI is that it permitted estimation of production functions for N and P, generally considered the most limiting nutrients in Rwanda. The disadvantage is that the trials were conducted with a basal dose of potassium (K). Strictly speaking, the fertilizer response obtained is relevant only if levels of K in farmers' soils are approximately the same as those levels used in the trials. As collateral studies in Rwanda have seldom identified a positive response to applications of K (FAO 1995, for example), it is generally thought that current K levels in Rwandan soils are adequate and the basal dose used in the trials was not necessary. Nevertheless, soil scientists attending the December 15, 1999, Workshop on Fertilizer Profitability expressed concern that funding be allocated for soil tests to update information on K levels (particularly in zones where K-consuming tubers are important crops) and to monitor K levels for vulnerable soils and crops if farmers do begin to use DAP instead of NPK on a broad scale. For the FSRP study, most response data were for a treatment that used NPK in the standard fixed proportion (17-17-17). The disadvantage here is that it is impossible to separate the effects of the different nutrients so the v/c ratios simply indicate whether the tested treatment is now profitable or not.

The manure issue. The FAO/SFI trial data as well as many of the FSRP sources of fertilizer response data fail to provide information for a pure control plot -- i.e., one without any manure. Furthermore, the quantities of manure are seldom clearly specified. This renders the interpretation of the results difficult as we do not know what the response to the fertilizer would be if a farmer were unable to apply the same amount of manure as was applied in the trials. Our inability to know what would happen in the absence of the basal dose of manure suggests that the extension program should stress the importance of manure being used in combination with inorganic fertilizers rather than as a substitute for them.⁴ In the FSRP database, there are some examples of NPK and or DAP response without a basal dose of manure – few of these were profitable and they are therefore not summarized in this report. There were also a few examples of crop response to manure only (no inorganic fertilizers) – none of these cases are reported here as they were never more profitable than the treatments using chemical fertilizers either alone or in combination with organic matter. Future fertilizer research needs to take the manure issue into account by designing true control plots so one can evaluate manure and fertilizer response independently as well as the interaction effects.

The lime issue. The FAO/SFI trials in zone 5a (Hautes Terres de Bufundu et Bushiru) used a basal application of lime (2.5 tons) at the head of each 4-season rotation. Although the lime cost was not taken into account when identifying the economically optimum dose of N and P, an effort has been made to examine the potential impact on overall profitability (v/c ratio) of the lime application in the potato section of this synthesis. The treatment of lime in studies reviewed by FSRP was variable, in some cases data permitted the inclusion of lime application costs in the v/c ratio calculation and in other cases it did not (in the latter case, lime was applied to both the control and the test plot). None of the FSRP cases using lime fell into the profitable category, hence they are not referred to in this synthesis report. The lack of strong profitability of lime treatments in the limited number of cases examined by the FSRP study suggests a need for further research in this area.⁵

The site/observation issue. Many of the sources consulted by FSRP were syntheses of results from multiple sites and/or years of trials and demonstrations. Documentation was frequently very poor concerning the number of observations used to calculate average yield response and the variability (e.g., a standard deviation or coefficient of variation). This limited our ability to compare the relative strength of results from different reports and evaluate the risk associated with fertilizer use (e.g., percent of plots with low yield response). Although the FAO/SFI data base permitted some analysis of variability in yield response across time and space, this has not yet been done.

⁴ Weight and Kelly (1999) present an extensive review of literature on fertilizer/organic matter complementarities in Africa and elsewhere. The implications for maintaining soil quality and increasing productivity are thoroughly discussed.

⁵ An extensive literature review of lime use in Rwandan agriculture has recently been completed by Frank R. Beernaert (1999); we did not receive a copy of this early enough to include it in our review.

The improved practices issue. Another problem encountered in sources consulted by FSRP was the allusion to improved practices having been used with the fertilizer treatment but a failure to clarify exactly what this included. It generally appeared to include some combination of an improved seed variety (with the variety not always being specified), spacing techniques, fertilizer application techniques (broadcasting versus placing it in the seed pocket or on the seeding line), and other unspecified practices. Information was lacking on the labor implications of applying fertilizer and using these improved practices, so no effort was made to account for increased labor costs. Although evidence from other countries suggests that fertilizer application itself does not require a great deal of additional labor, fertilizer use may also increase demand for planting, weeding, and harvest labor. If the additional labor is substantial, it should be quantified and the costs added to the costs of using fertilizer.

2.3.2. *Input prices*

Prices used by FAO/SFI reflect the price situation at a specific point in time (late 1999) and a system of pan-territorial pricing that does not reflect the true costs of transport to zones that are far from Kigali. FSRP prices are estimates for May 1999 rather than actual import costs encountered toward the end of 1999, but use a variety of sources that permitted two input price scenarios: a low -cost scenario using lowest estimates of both fertilizer and transport costs and a high-cost scenario using the highest cost estimates. In general, even the low -cost scenario for FSRP proved to be more expensive than the FAO/SFI price estimates.

Given the differences in the input prices used, FAO results – all else equal – are likely to be more profitable than FSRP results. This effect is more pronounced for zones further from Kigali where the benefits of the pan-territorial pricing policies are greater.

2.3.3. *Output prices*

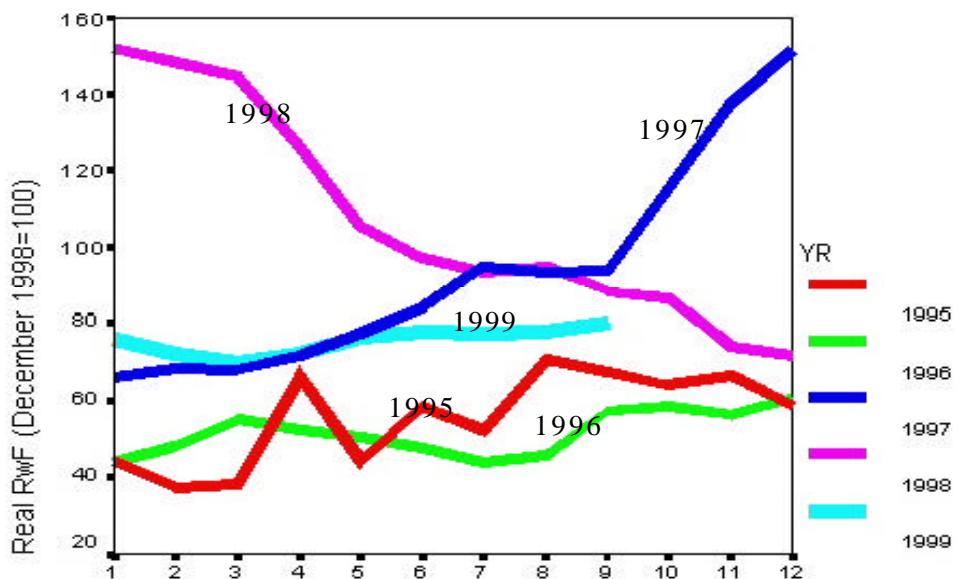
The key difference in output prices is similar to that of input prices. The FSRP analysis uses several price scenario while the FAO/SFI analysis uses prices at a single point in time. That point in time - September/October 1999 - represents a time of year when prices for many crops tend to be low. Hence, the impact – all else equal – is to make FAO/SFI v/c ratios lower than they would be using average annual prices. Using 1999 prices appears to be a reasonable choice as a review of post war price trends (real prices using December 1998 as a base) suggests that the post-war price volatility was finally diminishing: after two years of very low prices (1995-1996) followed by two years of unusually high prices (1997-1998), prices seem to have settled about mid-way between the two extremes and remained relatively stable up through September 1999. This is illustrated in Figure 2 (p.12), using the case of maize prices as an example.

FSRP analysis uses average real monthly prices calculated across all the post-war years. Two scenarios were examined. A high-price scenario using the average price for the 3-4 months of the year where there are shortages versus a low -price scenario assuming the farmer sells at or shortly after harvest time.

When calculating v/c ratios, input and output prices were combined to produce an optimistic and a pessimistic scenario: the optimistic one uses high output prices and low fertilizer and transport prices while the pessimistic one uses low output prices and high fertilizer and transport prices. In this synthesis we have reported only the midpoint value between the

optimistic and pessimistic v/c ratio estimates for simplicity, but the full FSRP report shows the range of outcomes.

Figure 2. Real Price Trends for Maize: 1995-1999



3. SUMMARY OF KEY FINDINGS ON FERTILIZER PROFITABILITY

This section of the paper contains a crop by crop synthesis of key findings on fertilizer response and profitability plus the authors' interpretation of what these results imply for the development of fertilizer promotion programs that could be launched by government extension services in collaboration with farmers' associations, supporting NGOs, fertilizer importers and distributors, and others involved in providing research, extension, and other support services to farmers.

We have used what we call the '**traffic light**' approach to mapping the joint findings of the FSRP and FAO/SFI studies (Figure 3). A color-coded map using the traffic light colors of red, yellow, and green synthesizes the joint recommendations for each crop analyzed. The three color categories represent three different recommendations:

Red indicates that fertilizer promotion IS NOT recommended;
Yellow indicates that a *targeted program* with careful monitoring is recommended; and
Green indicates that a *strong fertilizer promotion program* is recommended.

In addition to the traffic light colors, the maps also contain a large number of communes shaded in grey or white. Grey indicates crop/zone combinations where the results of both studies were inconclusive and it is necessary to find more information about the underlying response functions examined or to identify additional sources of data. White areas are those for which no fertilizer response data were found for the crop and zone.

Several different zoning systems have been developed for Rwanda. We have used the 18-zone system developed by James K. Gasana and adopted by the National Committee for Agriculture (NCA) in 1991 and as illustrated in Figure 4.

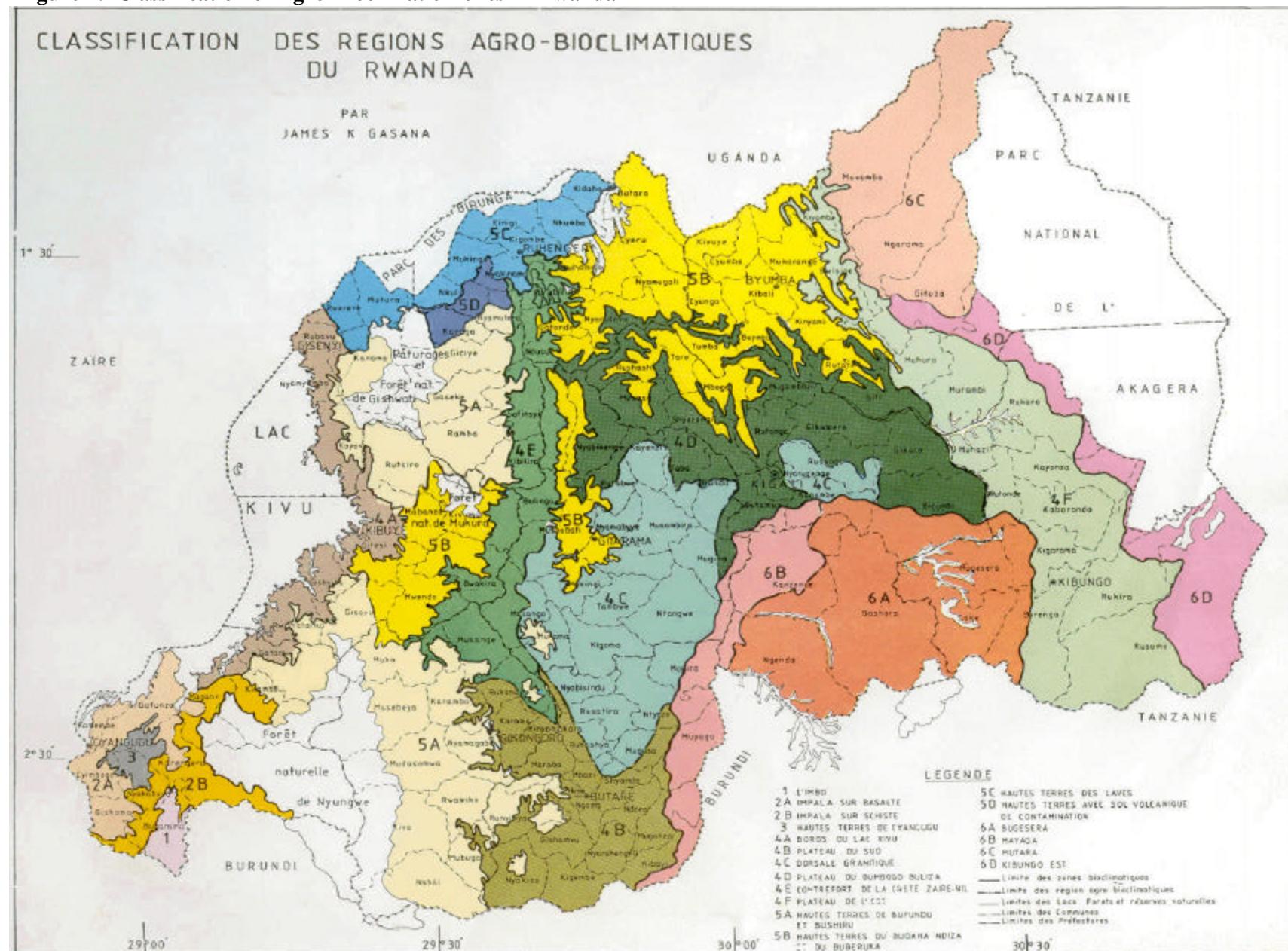
Each 'traffic -light' map is accompanied by a one -page synthesis of the key profitability results by agrobioclimatic zone (fertilizer treatments used, yield response, price assumptions, and estimated v/c ratios).

Results for the five principal crops are presented first (climbing beans, maize, rice, sorghum, and potatoes), followed by results for the six crops covered only by the FAO/SFI study (soybeans, sweet potatoes, cabbage, peas, wheat, and cassava).

Figure 3. Traffic Light Guide to Fertilizer Mapping



Figure 4: Classification of Agro-Bioclimate Zones in Rwanda



3.1. Recommendations for Climbing Bean Fertilization

The profitable fertilizer treatments identified by the research are described in Table 2 below and the 'traffic light' recommendations are mapped in Figure 5 on the next page. A strong program of fertilizer promotion for climbing beans will result in profitable outcomes for farmers in the zones appearing in Table 2. As most v/c ratios are substantially greater than two, profitability will be maintained even if bean prices fall or fertilizer prices rise somewhat.

Table 2. Profitable Fertilizer Treatments for Climbing Beans, by Zone

Zone	Treatment*	Yield Response (kg/ha)	Markets	Bean Prices (RwF)**	V/C Ratio
1 – Imbo	80 kg DAP 30 kg urea	766	Kamembe	100	3.2
4b – Plateau du Sud	120 kg DAP 10 kg urea	1181	Butare	120	5
4c – Dorsale Granitique	120 kg DAP 10 kg urea	1181	Ruhango	110	4.4
4d – Plateau du Bumbogo -Buliza	100 kg DAP	365	Kigali Ville Butare	134/175 123/200	2.3 2.4
4f -Plateau de l'Est	100 kg DAP	1020	Gatore Kibungo	101/147 103/167	5 5.5
5c – Hautes Terres de Laves	80 kg DAP 40 kg urea	797	Ruhengeri	100	3.1

*All treatment results based on application of 2-5 tons of manure/hectare on both test and control plots.

** When one price is shown analysis was done using the nominal market price for Sept/Oct 1999; when two prices are shown analyses used average prices from 1995-1999 (base = Dec 1998) and two scenarios: (1) average prices during harvest period and (2) average prices during scarcity period. For the latter case, the v/c ratio is an average of the two scenarios.

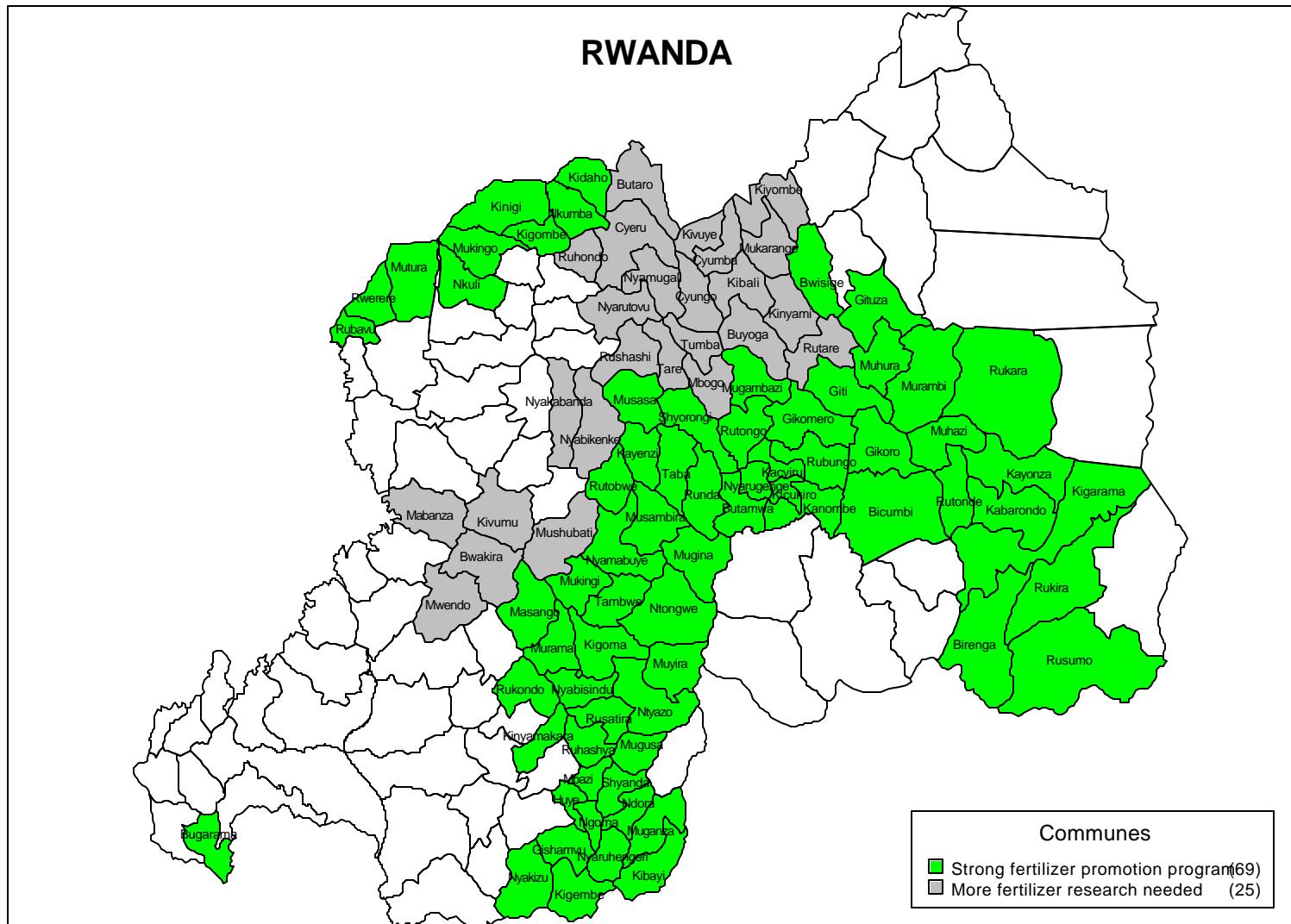
The highest v/c ratios were found for zone 4f. Although these results are promising, it is important to keep in mind that rainfall in the zone is more variable than elsewhere increasing the risk of low yield response when rains are not adequate.

Other results (not shown in the table) suggest that if K levels are adequate, use of NPK plus urea in lieu of DAP is not profitable (v/c<2) or considerably less profitable than the DAP treatments shown in the table. We also had results suggesting that using only manure (10T/ha) is not profitable (v/c = 1.63 when manure valued at prevailing cost of 5 RwF/kg) in zone 4d; we do not know the extent to which this is true in other zones.

Results for zone 5b (Hautes Terres du Budaha, Ndiza and Buberuka) were inconclusive. A variety of demonstrations using 100 kg of DAP/ha produced v/c ratios that varied substantially across years (from 1.3-2.1 using Kigali Ville prices and response data covering seasons 1991A and 1988B) or were just slightly below 2 (1.8-1.9) using Ruhengeri market prices and response data from several sites for 1992A.

There are many other zones with potential for climbing bean production (e.g., zones 4a (Bords du Lac Kivu), 6a (Bugesera), 6b (Mayaga), 6c (Mutara); and 6d (Kibungo Est) but response data were not found for them. Despite the potential in zones 6 (a-b-c-d), the sensitivity of climbing beans to inadequate rains remains an important obstacle to overcome.

Figure 5. Climbing Beans: Map of Fertilizer Promotion Recommendations for Rwanda



3.2. Recommendations for Maize Fertilization

Profitable fertilizer treatments for maize are shown in Table 3 and mapped in Figure 6. A strong program of maize fertilizer promotion in zones 2a, 2b, 4c, 4d, 5b and 5c will result in profitable outcomes. In the case where the v/c ratio is much higher than 2 (zones 2 and 5b) profitability will be maintained even if the price of fertilizer or maize changes slightly because fertilizer response is relatively strong. In zone 5b, the NPK/urea combination is profitable, but the profits would probably be even better with a DAP/Urea combination (data to confirm the hypothesis are not available). In zone 4d, the FAO/SFI study used the relatively high Kigali maize price (150 RwF/kg). The FSRP study used lower prices (85-123 RwF/kg) which give results at the cut-off point (v/c = 2). The Kigali market price has a positive influence on profitability for zone 4c (v/c = 2.6 whereas the v/c is only 2.2 when one uses the Ruhango market price). Given the generally higher maize prices observed around Kigali Ville, a strong program of fertilizer promotion in the area seems warranted, but with close monitoring of the market prices to avoid losses if prices fall. Other results (not shown in the table) indicate that the use of NPK/urea instead of DAP/urea in zones 2, 4c, 4d, and 5c is generally not profitable ($v/c < 2$) or considerably less profitable than the treatments presented in the table (assuming adequate levels of K).

The results obtained for zones 4b, 5a, 6c, and 6d are inconclusive due to the lack of detailed documentation on the demonstrations and tests. Traditionally two of these zones (5a and 6c) are maize producers. There are also zones 4a, 4f, 6a, and 6b where the lack of response data does not permit us to evaluate profitability. Due to limited maize research in the past, there are more 'gray' areas for maize than other crops. Another consideration is the high moisture requirement for maize; in follow-up studies, it will be important to consider the issue of irrigation, especially in the rain deficit zones (zones 6a-b-c-d).

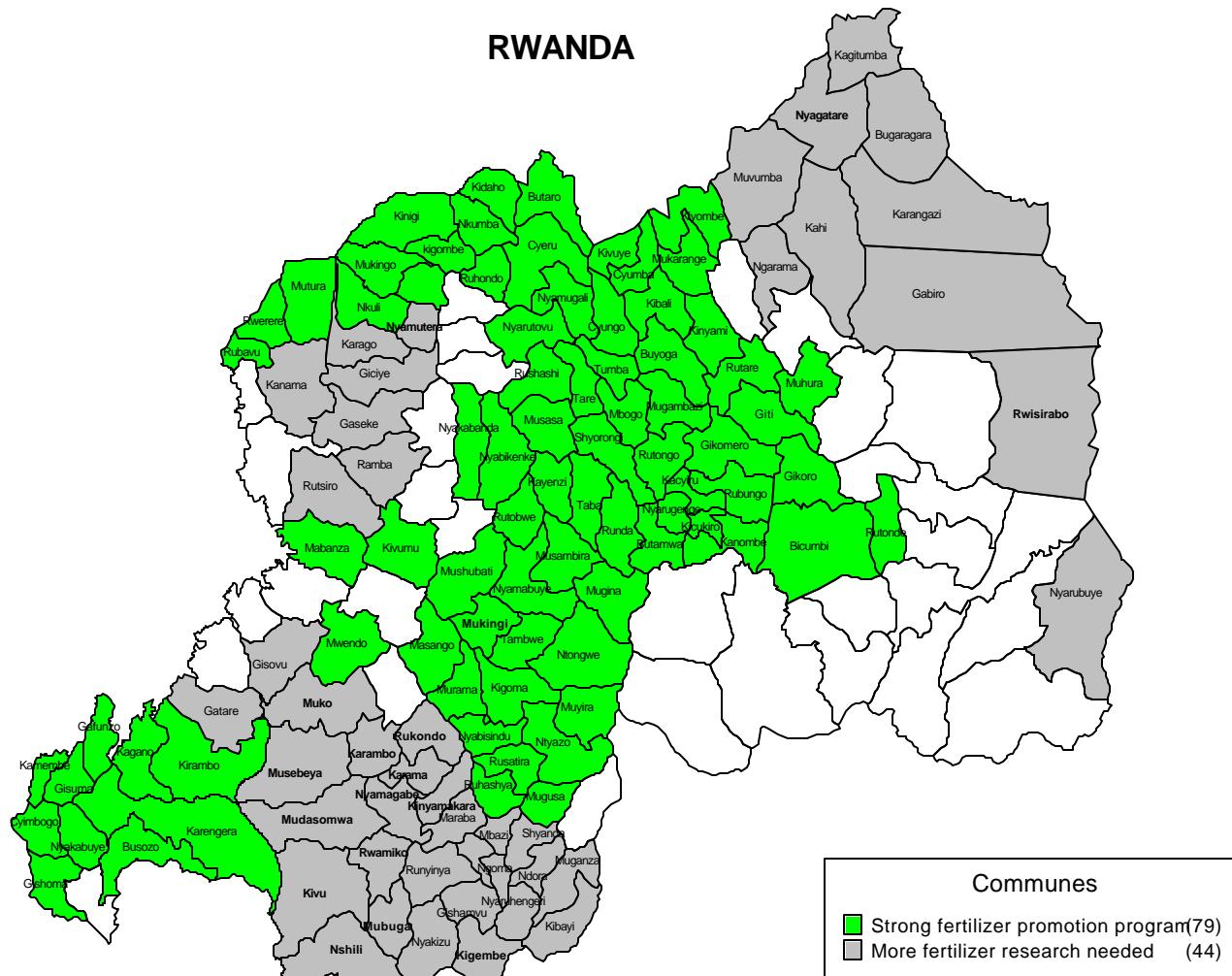
Table 3. Profitable Fertilizer Treatments for Maize, by Zone

Zone	Treatment*	Yield Response (kg/ha)	Markets	Maize Price (RwF/kg)**	V/C Ratio
2a/b-Impala	90 kg DAP 120 kg Urea	1604	Kamembe	100	3.6
4c-Dorsale Granitique (bas -fonds)	60 kg DAP 60 kg Urea	818	Ruhango Kigali-Ville	70 85/123	2.2 2.6
4d-Plateau du Bumbogo -Buliza	90 kg DAP 110 kg Urea	747	Kigali-Ville	150 85/123	2.6 2
5b-Hautes Terres du Budaha-Ndiza-Buberuka Bub	250 kg NPK 100 kg Urea 300 kg NPK	1558 2613	Kigali-Ville Ruhengeri	85/123 69/79	2.9 2.9
5c-Hautes Terres de Laves	70 kg DAP 80 kg Urea	962	Byangabo	70	2.1

*All results based on application of 1-10 tons of manure/hectare on both test and control plots.

** When one price is shown analysis used the nominal price for Sept/Oct 1999; when two prices are shown analyses used average 1995-99 real prices (base = Dec 1998) and two scenario: (1) average prices during harvest and (2) average prices during scarcity period. For the latter, the v/c ratio is average of two scenarios.

Figure 6. Maize: Map of Fertilizer Promotion Recommendations for Rwanda



3.3. Recommendations For Rice Fertilization

Data for rice response to fertilizer were found for zones 4b and 6b only (Projet Rizicole Butare); recommendations based on these data are summarized in Table 4 and mapped in Figure 7 on the next page. The results confirm that fertilizer can be strongly promoted on rice in zones 4b and 6b. The most profitable treatment was a DAP/urea combination with a v/c ratio of 3.9 estimated using prices offered for paddy at the Gikonko market. Although all other treatments examined also exhibited v/c ratios >2, our recommendation is that a program to promote the most profitable treatment be initiated.

Table 4. Profitable Fertilizer Treatments for Rice, by Zone

Zone	Treatment	Fertilizer Response (kg/ha)	Markets	Rice Prices (Rwf)*	V/C Ratio
4b/6b - Projet Rizicole Butaré in Plateau du Sud & Mayaga	50 kg DAP	1431	Gikonko (paddy)	85	3.9
	90 kg urea				
	140 kg NPK	1431	Gikonko (paddy)	85	2.9
	50 kg urea				
	100 kg DAP	951	Gikonko (paddy) Butaré (riz)	85 180	3.2 6.7
	100 kg DAP	1604	Gikonko (paddy)	85	3.2
	100 kg urea		Butaré (riz)	180	6.2
	250 kg NPK	1681	Gikonko (paddy)	85	2.0
	100 kg urea		Butaré (riz)	180	3.9

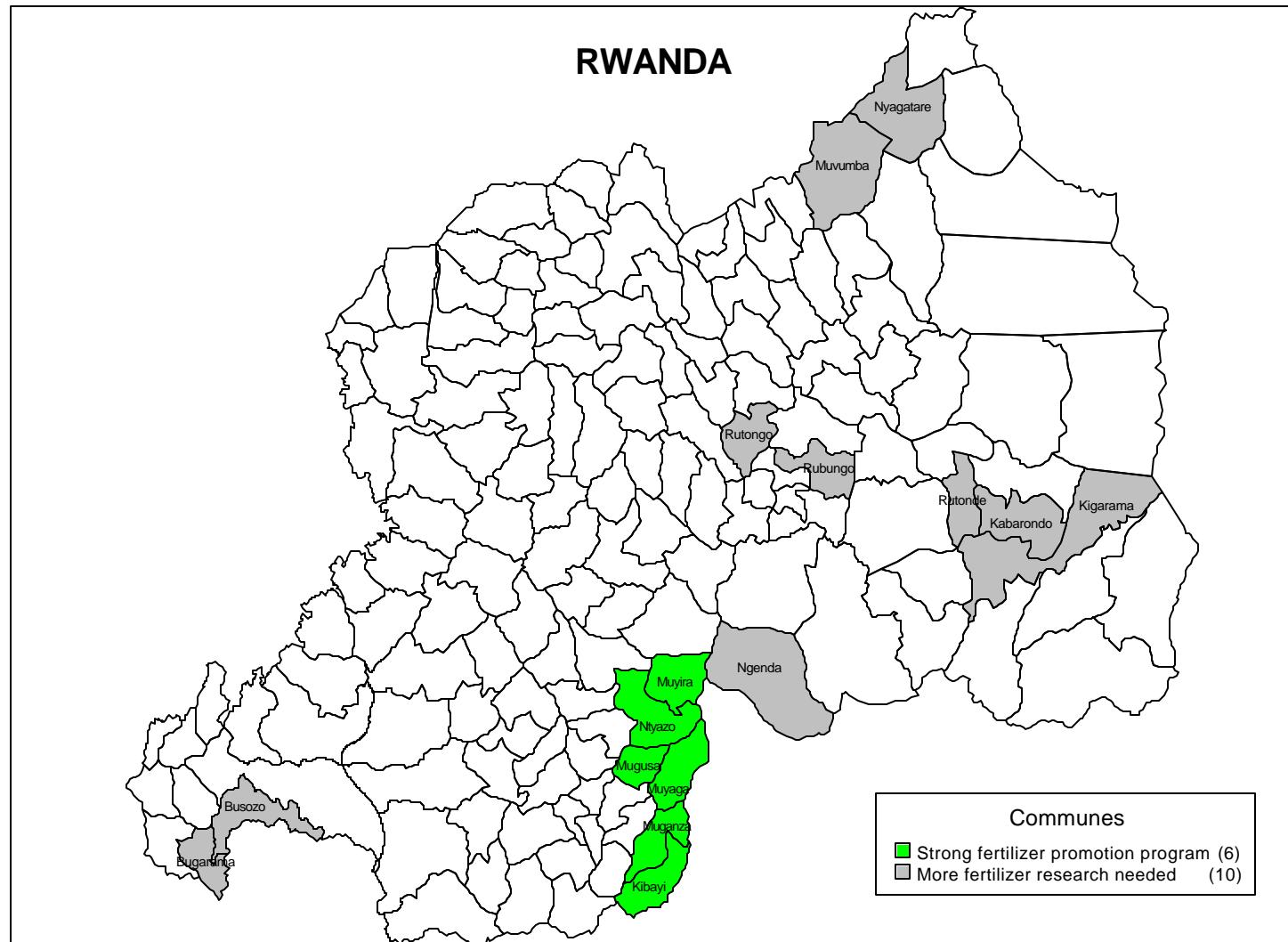
*When one price is shown analysis used nominal market price for Sept/Oct 1999; when two prices are shown analysis used average prices from 1995-1999 (base=Dec 1998) and two scenario: (1) average of prices during the harvest period and (2) average prices during the scarcity period. For the latter case, v/c ratios shown are an average of the two scenario.

We also report a few v/c ratios calculated using the price of processed rice at the Butare market. These analyses show that the margin between paddy and processed rice is quite large, raising the question of whether farmers (or farmers' associations) could increase rice income by selling a processed product with more value added - an approach to raising rural incomes that has met with some degree of success elsewhere (Mali, Senegal).

Assuming the GOR decides to promote the DAP/urea package for rice, it is recommended that some program for monitoring changes in soil quality be included in the program. Key information to monitor would be: (1) declines in levels of potassium (K) available in the soil as the current recommendation does not include K and (2) increased incidence of 'pyriculariase' which can be brought about by applying too much nitrogen.

Given that we have only found response data permitting analysis of fertilizer/rice technologies in two zones, it is important to identify additional data sets permitting profitability analyses for other zones (zone 1 for the rice perimeters at Bugarama, 4d for Kabuye, 4c/6b for Mukunguri, 4f for Rwamagana; and 6c for Mutara). If such data do not exist, it seems appropriate to design some fertilizer trials or demonstrations capable of providing good response data because the current variability in yields across these zones suggests that generalizing recommendations from one zone to another is not appropriate.

Figure 7. Rice: Map of Fertilizer Promotion Recommendations for Rwanda



3.4. Recommendations for Sorghum Fertilization

Profitable fertilizer treatments for sorghum are shown in Table 5 and mapped in Figure 8. A strong program of sorghum fertilizer promotion is recommended in zones 4d (Plateau du Bumbogo-Buliza) and 6a (Bugesera) where the v/c ratio is much greater than 2. Profits are lower yet still reasonable for producers in zones 4b (Plateau du Sud) and 4f (Plateau de l'Est), but sorghum prices in these zones need to be monitored carefully as small price changes could bring the v/c ratios below 2. This is particularly true for zone 4b where the current profitability is due more to the high output prices (110/143 RwF/kg) than to the fertilizer response (only 576 kg/ha versus 807 kg/ha in the Kibungo area for the same treatment). Other results (not shown in the table) indicate that the use of NPK/urea instead of DAP/urea, in zones where K is sufficient, is generally not profitable ($v/c < 2$) or considerably less profitable than the treatments shown in the table.

Results obtained from zone 4c (Dorsale Granitique) are inconclusive (mainly due to insufficient data on the number of repetitions) whereas this zone is traditionally a producer of sorghum. There are also zones 5c (eastern part of Hautes Terres de Laves), 6b (Mayaga), and 6d (Kibungo Est) where we have insufficient fertilizer response data to evaluate fertilizer profitability. For all the cases where we have insufficient fertilizer response data, we have the following practical recommendations: (1) try to find data on fertilizer response trials carried out in the past; (2) if there is no data available for these zones, verify whether fertilizer response data from similar zones may be applicable to these zones; (3) if the two options above are not possible then conducting new fertilizer trials or demonstrations is recommended in the zones considered as priority for a particular crop. In designing fertilizer promotion programs, we should take into account the fact that sorghum is much more tolerant to lack of moisture than maize. This suggests that in the zones where the v/c ratios are > 2 for both maize and sorghum (e.g. zone 4d) maize could be cultivated in the swamps under irrigation and sorghum could be cultivated on the hills.

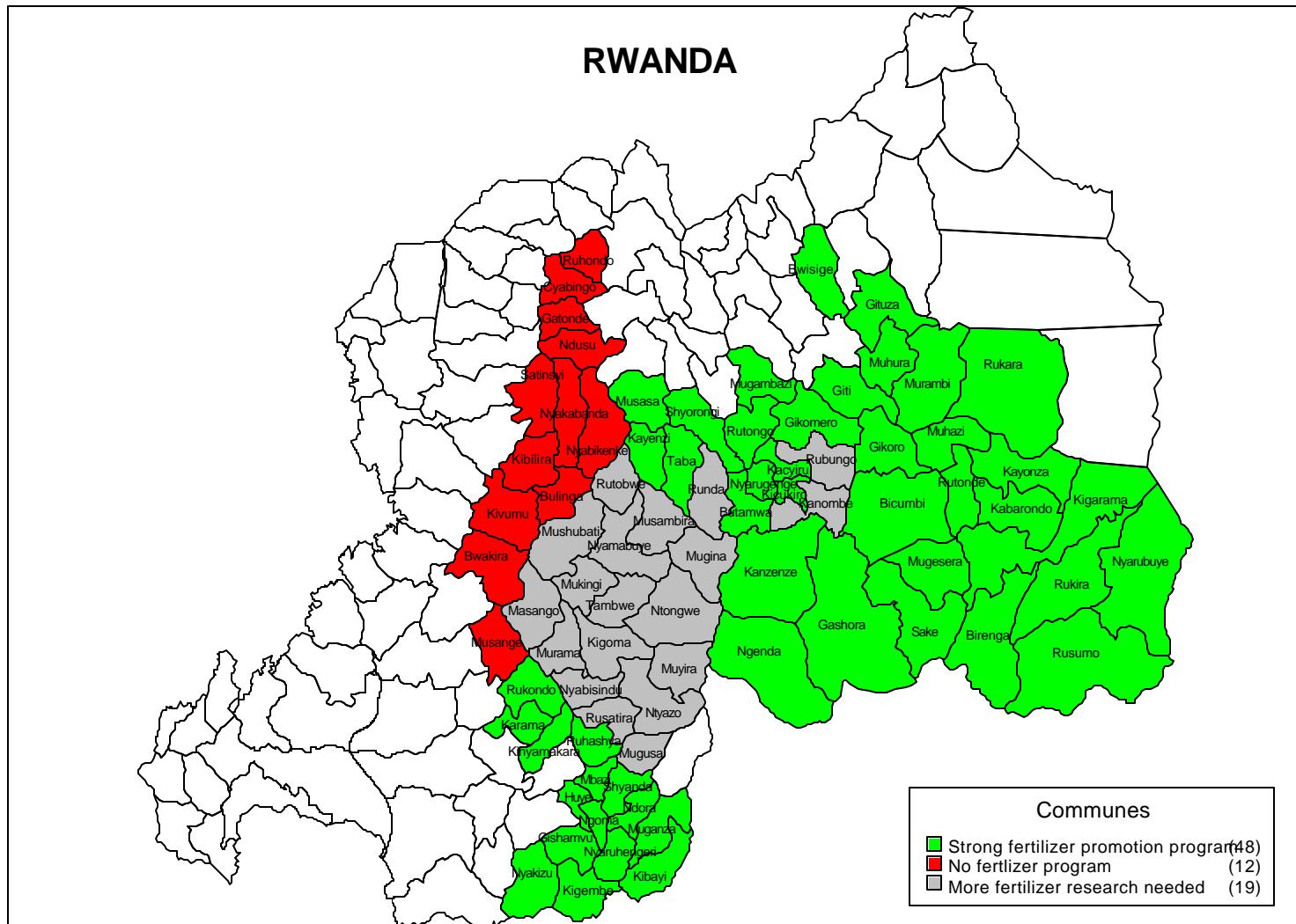
Table 5. Profitable Fertilizer Treatments for Sorghum, by Zone

Zone	Treatment*	Fertilizer Response		Sorghum Price (RwF/kg)**	V/C Ratio
		(kg/ha)	Markets		
4b-Plateau du Sud	76 kg DAP	576	Butare	143/110	2,1
	78 kg Urea				
4d-Plateau du B.-B.	90 kg DAP*	1357	Kigali-Ville	100	4,2
	70 kg Urea				
4f-Plateau de l'Est	76 kg DAP	807	Kibungo	114/82	2,3
	78 kg Urea				
6A -Bugesera	110 kg DAP*	1864	Nyamata	80	3,6
	80 kg Urea				

* All treatment results based on application of 1 -7 tons of manure/hectare on both test and control plots.

** When one price is shown analysis used nominal market price for Sept/Oct 1999; when two prices are shown analysis used average prices from 1995-1999 (base=Dec 1998) and two scenario: (1) average of prices during the harvest period and (2) average prices during the scarcity period. For the latter case, v/c ratios shown are an average of the two scenarios.

Figure 8. Sorghum: Map of Fertilizer Promotion Recommendations for Rwanda



3.5. Recommendations for Potato Fertilization

Profitable fertilizer treatments for potatoes are described in Table 6 and mapped in Figure 9. Table 6 shows that treatments using DAP and urea are more profitable than those using NPK.

Although v/c ratios are >2 for NPK treatments shown in zones 5b and 5c, it will be more profitable for farmers in these zones to use the DAP/urea treatments if the products are available. A strong program of promoting DAP/urea treatments is warranted in zones 2b (Impala sur schistes), 5a (Hautes Terres du Bufundu-Bushiru), 5b (Hautes Terres du Budaha - Ndiza-Buberuka) and 5c (Hautes Terres de Laves).

We have some reservations, however, about promoting potatoes in zones 2a (Impala sur basalte) and 4c (Dorsale Granitique), despite the very favourable profitability results.

Because conditions in these zones promote the spread of bacterial potato diseases, programs here must include a component to combat disease or potato production throughout Rwanda could be threatened.

Table 6. Profitable Fertilizer Treatments for Potatoes, by Zone

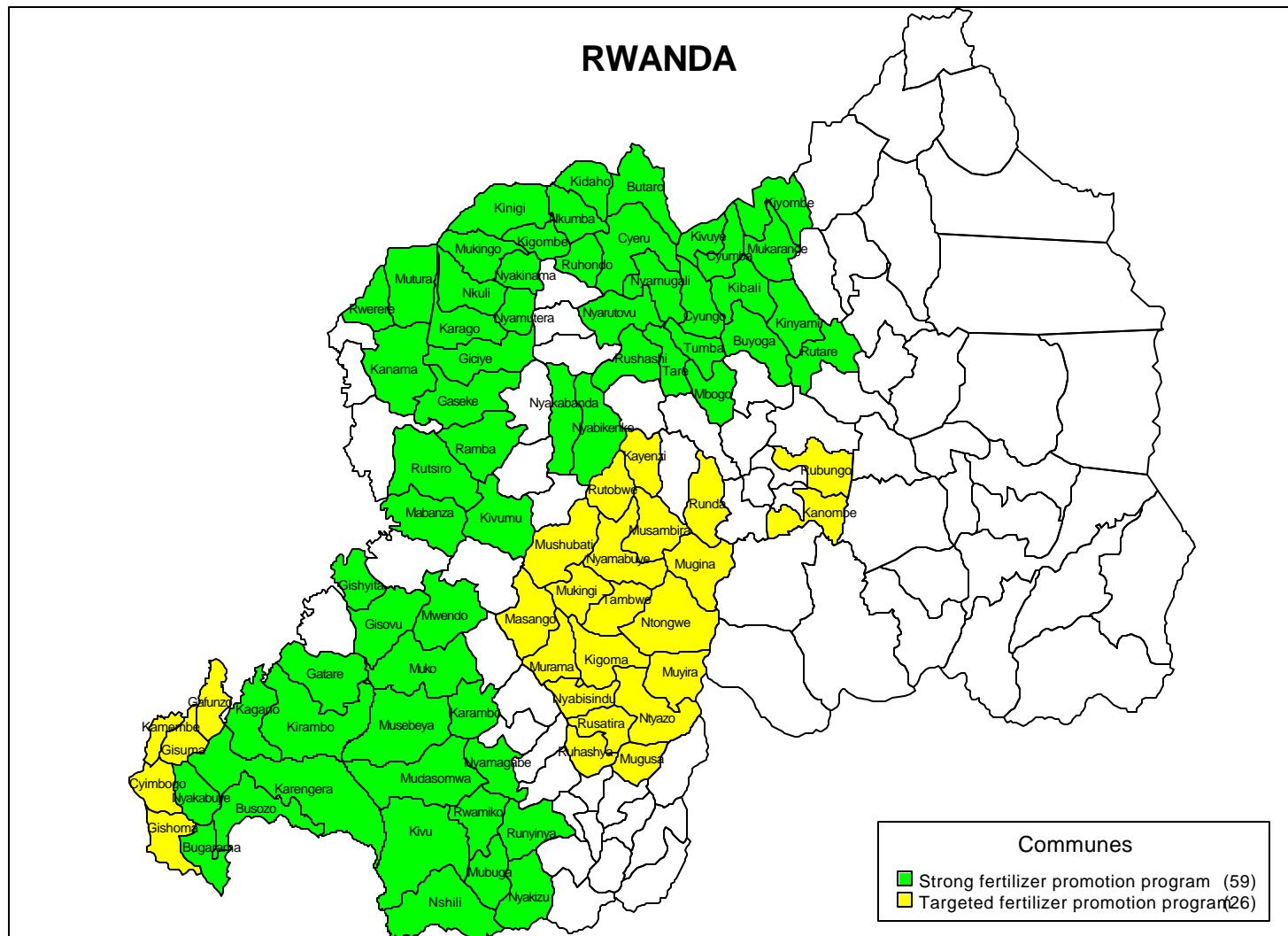
Zone	Treatment	Fertilizer Response (kg/ha)	Markets	Potato prices (Rwf)**	V/C Ratio
2a/b - Impala	110 kg DAP* 100 kg urea	5018	Kamembe	50	5
4c - Dorsale Granitique	150 kg DAP* 30 kg urea	8580	Ruhango	45	9.9
5a - Hautes Terres du Bufundu & Bushiru	110 kg DAP* 70 kg urea	9310	Gasarenda	50	12
5b - H.T. du Budaha, Ndiza & Buberuka	90 kg DAP* 70 kg urea 300 kg NPK 300 kg NPK	9063 3570 4500	Byumba Ruhengeri Kigali Ville	45 48/39 61/66	11.8 2.3 4.4
5c - Haute Terres des Laves	100 kg DAP* 50 kg urea 300 kg NPK + 10 T manure	11745 8258	Ruhengeri Byangabo Gisenyi Kora	35 44/38 41/49 35/41	12.7 2.9 3.1 2.6

*Treatment results based on application of 1-5 tons of manure/hectare on both test and control plots.

** When one price is shown analysis used the nominal price for Sept/O ct 1999; two prices indicate analysis was done with average real 1995-1999 prices (base = Dec 1998) and two scenario: average of prices during harvest period and average prices during scarcity period. For the latter case, v/c ratio is an average of the two scenarios.

The FAO/SFI study results reported in Table 6 above did not take into account the cost of 2500 kg/ha of lime applied once per 4-season rotation in zone 5a (Hautes Terres du Bufundu-Bushiru). Nevertheless, calculations show that taking this cost into account, fertilizer use remains profitable (v/c ratio >2). Additional calculations suggest that profitability will still be maintained in the long run even if one considers the costs of potassium (K) depletion due to the use of DAP rather than NPK. After subtracting costs for a dose of 100 Kg/ha of KCl (0-0-50), the v/c ratio remains greater than 2 (5.7 for zone 5a, 7.9 for zone 5b, and 7 for zone 5c). DAP/urea treatments tend to be more profitable than NPK/urea treatments, even when KCl supplements are taken into account.

Figure 9. Irish Potatoes: Map of Fertilizer Promotion Recommendations for Rwanda



3.6. Recommendations for Soybean Fertilization

Profitable fertilizer treatments for soybeans are shown in Table 7 and mapped in Figure 10. Note that these results were obtained using both manure and an inoculation procedure to biologically fix nitrogen (costs not taken into account because technologies were used on both test and control plots). A strong program of fertilizer promotion (in combination with inoculation) is recommended in all the zones studied: 2a (Impala sur basalte), 4b (Plateau du Sud), 4c (Dorsale granitique) and 4d (Plateau du Bumbogo-Buliza). As the v/c ratio in these zones is much greater than 2, fertilizer use should be highly profitable. The profits are highest in zone 4d due to good fertilizer response and the relatively high output prices found in the Kigali-Ville market (250 RwF/Kg).

Table 7. Profitable Fertilizer Treatments for Soybeans, by Zone

Zone	Treatment*	Fertilizer Response (kg/ha)	Markets	Soybean Prices (RwF/kg)**	V/C Ratio
2a - Impala sur basalte	60 kg DAP	418	Kamembe	180	4.3
	20 kg Urea				
	120 kg NPK	418	Kamembe	180	3
4b - Plateau du Sud	90 kg DAP	704	Butare	130	4.7
	230 NPK	704		130	1.9
4b - Bas fonds Plateau du Sud	80 kg DAP	811	Butare	130	5.4
	10 kg Urea				
	220 kg NPK	811	Butare	130	2.3
4c - Dorsale Granitique	90 kg DAP	613	Ruhango	180	5.6
	250 kg NPK	613		180	2.1
4d - Plateau du Bumbogo-Buliza	80 kg DAP	808	Kigali Ville	250	10.3
	10 kg Urea				
	230 kg NPK	808	Kigali Ville	250	4.2

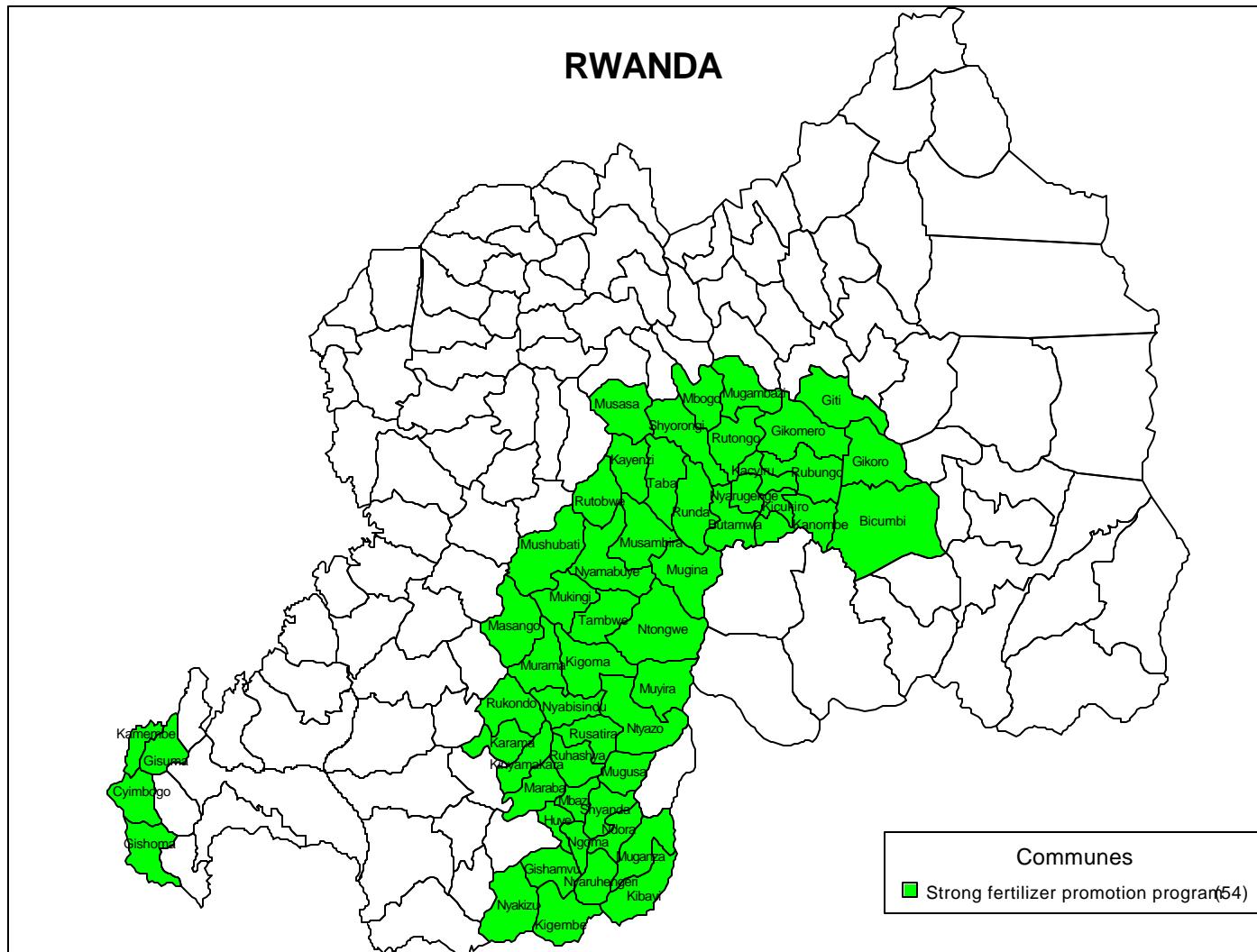
*All treatments based on 1-5 t/ha of organic matter and use of a biological nitrogen fixing inoculum.

** Analysis uses nominal output prices for September-October 1999.

Results obtained indicate that the use of NPK with rhizobium (inoculum) in soils that naturally have adequate levels of K is profitable on soybeans ($v/c > 2$); but often less profitable than the use of DAP/Urea or DAP combined with the biological fixation of nitrogen. It is always advisable to use the most profitable fertilizer combination when available.

We found no fertilizer response data for soybeans in zones 1 (Imbo), 4f (Plateau de l'Est), 6b (Mayaga) and 6c (Mutara); this appears to be a major gap as soybeans have potential to be rotated with rice in these zones. For these zones and zone 4a (Bord du Lac Kivu) where soybean production is progressively replacing beans, it will be important to collect response data permitting fertilizer profitability analyses in these zones.

Figure 10. Soybeans : Map of Fertilizer Promotion Recommendations for Rwanda



3.7. Recommendations for Sweet Potato Fertilization

Profitable fertilizer recommendations for sweet potatoes are presented in Table 8 and mapped in Figure 11. A strong program of fertilizer promotion for the production of sweet potatoes is recommended in the 3 zones studied – 4b (Plateau du Sud), 4c (Dorsale granitique), and 4d (Plateau du Bumbogo-Buliza). The v/c ratios are much greater than 2 in these zones and will allow farmers to earn high profits. The practical aspect of this observation is that fertilizer use in these zones will enable farmers to increase production per hectare thereby freeing up more land for other crops that have a higher protein content (climbing beans, soybeans, maize, rice, and sorghum), a higher vitamin content (vegetables), or a higher market value (potatoes or rice).

Profitability is highest in zone 4d with the use of DAP/Urea (v/c=7) due to good fertilizer response and the high price of sweet potatoes on the Kigali market (40 RwF/Kg versus 25 RwF/Kg at Ruhango or 30 RwF/Kg at Butaré). The high profitability registered in the Dorsale Granitique lowlands (RVC=5) is due to the unusually strong fertilizer response recorded for sweet potatoes in the zone.

Results obtained indicate that the use of NPK/Urea or NPK in soils that naturally possess sufficient quantities of K is profitable on sweet potatoes (v/c>2); but DAP/urea is more profitable.

Response data were not found for zones 4f (Plateau de l'Est), 6a (Bugesera), and 6b (Mayaga) where sweet potatoes are also an important crop. It would be useful to find data permitting profitability analyses for these zones.

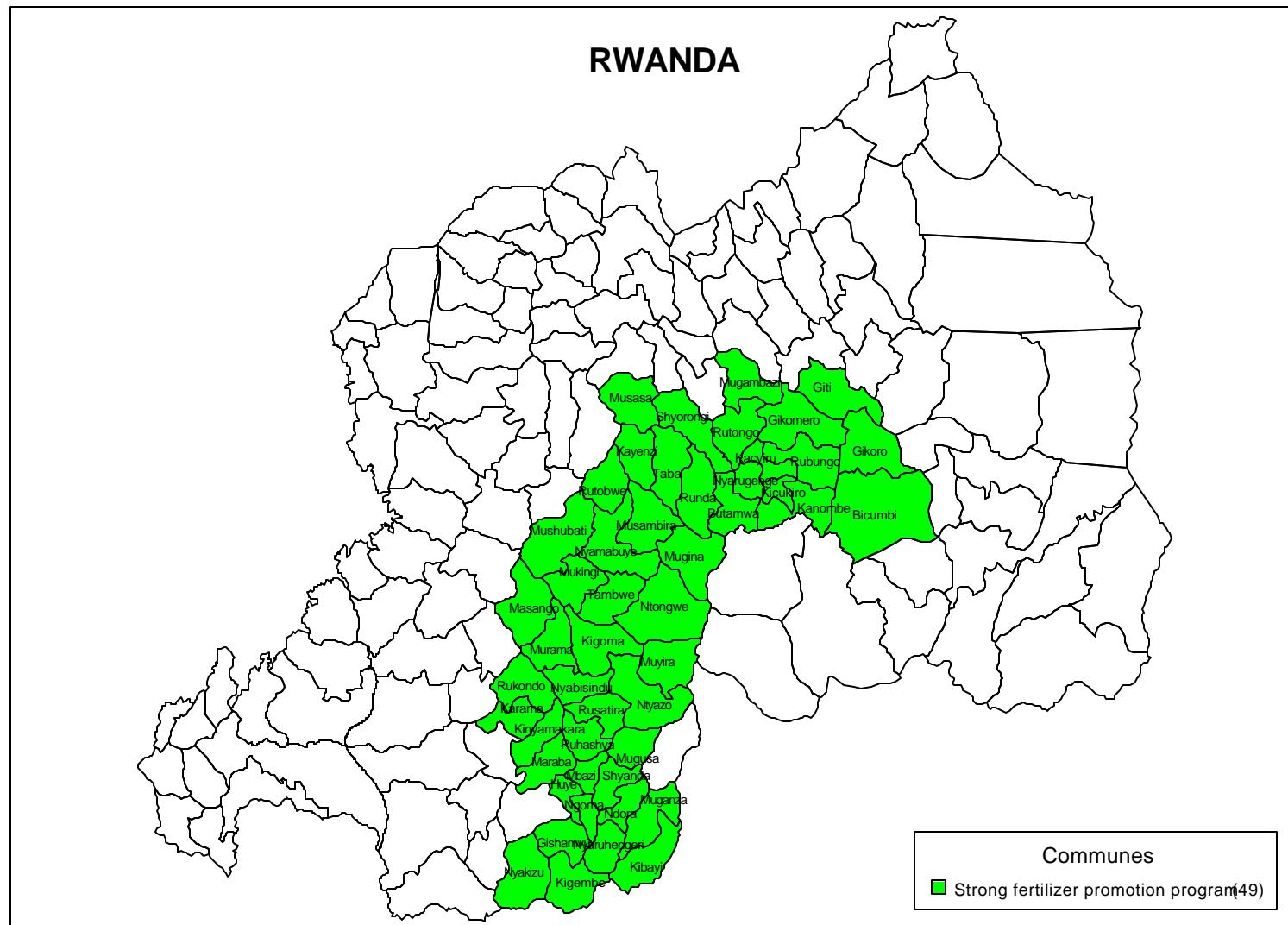
Table 8. Profitable Fertilizer Treatments for Sweet Potatoes, by Zone

Zone	Treatment*	Fertilizer Response (kg/ha)	Markets	Sweet Potato Prices ** (RwF/kg)	V/C Ratio
4b – Plateau du Sud	80 kg DAP	4151	Butare	30	3.1
	110 kg Urea				
	200 kg NPK	4151	Ruhango	25	2.5
	40 Urea				
4c – Dorsale Granitique	80 kg DAP	4151	Butare	30	2.9
	110 kg Urea				
	200 kg NPK	4151	Ruhango	25	2.3
	40 Urea				
4c- Bas fonds Dorsale Granitique	120 kg DAP	7390	Ruhango	25	5
	50 kg Urea				
	310 kg NPK	7390	Ruhango	25	2.9
4d – Plateau du Bumbogo- Buliza	120 kg DAP	5729	Kigali-Ville	40	7
	30 kg Urea				
	330 kg NPK	5729	Kigali-Ville	40	3.3

*All results based on application of 1-8 t/ha of manure.

** Analyses done using September-October 1999 nominal prices.

Figure 11. Sweet Potatoes: Map of Fertilizer Promotion Recommendations for Rwanda



3.8. Recommendations for Cabbage Fertilization

Profitable fertilizer recommendations for cabbage are presented in Table 9 and mapped in Figure 12. A strong program of fertilizer promotion for the production of cabbage is recommended in the low-lands of zone 4b (Plateau du Sud) covered by this study. The v/c ratio is much greater than 2 due to very good fertilizer response (91% increase in production per hectare). This situation will allow farmers in zone 4b to make substantial profits even if there is a decrease in cabbage prices at Butaré market. Even at a very low output price of 5 RwF/kg, DAP/urea fertilization remains profitable.

Results in Table 9 show that the use of NPK/urea in soils that naturally possess sufficient quantities of K is profitable in the marshlands of zone 4b (Plateau du Sud) (v/c=8.6), but profitability is even greater with the use of DAP/urea (v/c=13.6).

Other agrobioclimatic zones favorable to vegetable production should be studied so as to acquire reliable data for the appraisal of fertilizer profitability on cabbage and other vegetable products. In the case where there is no reliable data, new demonstrations and trials should be conducted with priority being given to the semi urban areas due to their proximity to regions of high demand.

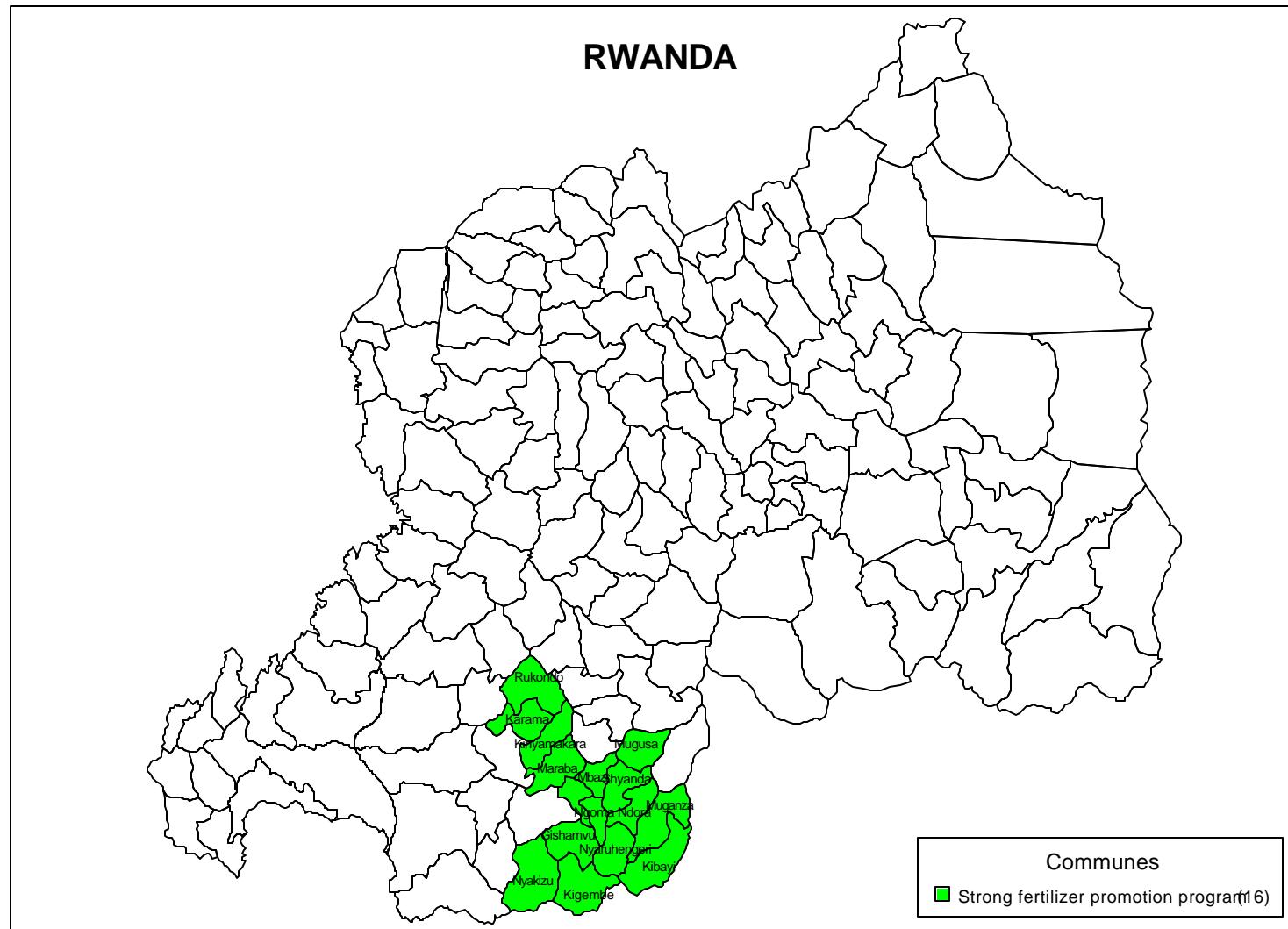
Table 9. Profitable Fertilizer Treatments for Cabbage, by Zone

Zone	Treatment*	Fertilizer Response (kg/ha)	Markets	Cabbage Prices** (RwF/kg)	V/C Ratio
4b -Bas fonds	160 kg DAP	28310	Butaré	30	13.6
Plateau du Sud	130 kg Urea				
	440 kg NPK	28310	Butaré	30	8.6
	30 kg Urea				

*All results based on manure application of 5-10 T/ha.

**Analysis done using September-October 1999 nominal prices.

Figure 12. Cabbage: Map of Fertilizer Promotion Recommendations for Rwanda



3.9. Recommendations for Peas, Wheat, and Cassava Fertilization

The FAO/SFI analyses also examined fertilizer response data for peas, wheat, and cassava in several zones. The results are mapped in Figures 13-15 where the color red predominates, illustrating that none of these crops appear to be good candidates for fertilizer promotion programs.

By way of summary, we note that:

- Fertilizer application on peas is not recommended in zone 5a (Hautes Terres du Bufundu-Bushiru); the cost of liming contributes strongly to the low profitability.
- Wheat, which responds well to fertilizer in zone 5a (Hautes Terres du Bufundu-Bushiru) and 5b (Hautes Terres du Budaha, Ndiza et Buberuka), is not able to repay the fertilizer cost in this zone due to a very low market prices at present.
- Fertilizer profitability on cassava is not assured in zone 4c (Dorsale Granitique) although this is one of its principal zones of production. The low profitability is due to the fact that the production cycle of cassava ties up a given unit of land for 4 agricultural seasons; although returns to fertilizer are high, returns to land are low relative to other cropping options which permit a new harvest every six months.

For these three crops (peas, wheat, and cassava), the red color has been used on the maps in the zones studied. It is however advisable to locate data on fertilizer use on peas in zone 4b (Hautes Terres du Budaha, Ndiza et Buberuka) and on cassava in zones 6 (a-b-c-d). It is also necessary to monitor the market price of wheat in the production zones (5a and 5b) so as to take advantage of any changes in profitability that might come about if output prices rise.

Figure 13. Peas: Map of Fertilizer Promotion Recommendations for Rwanda

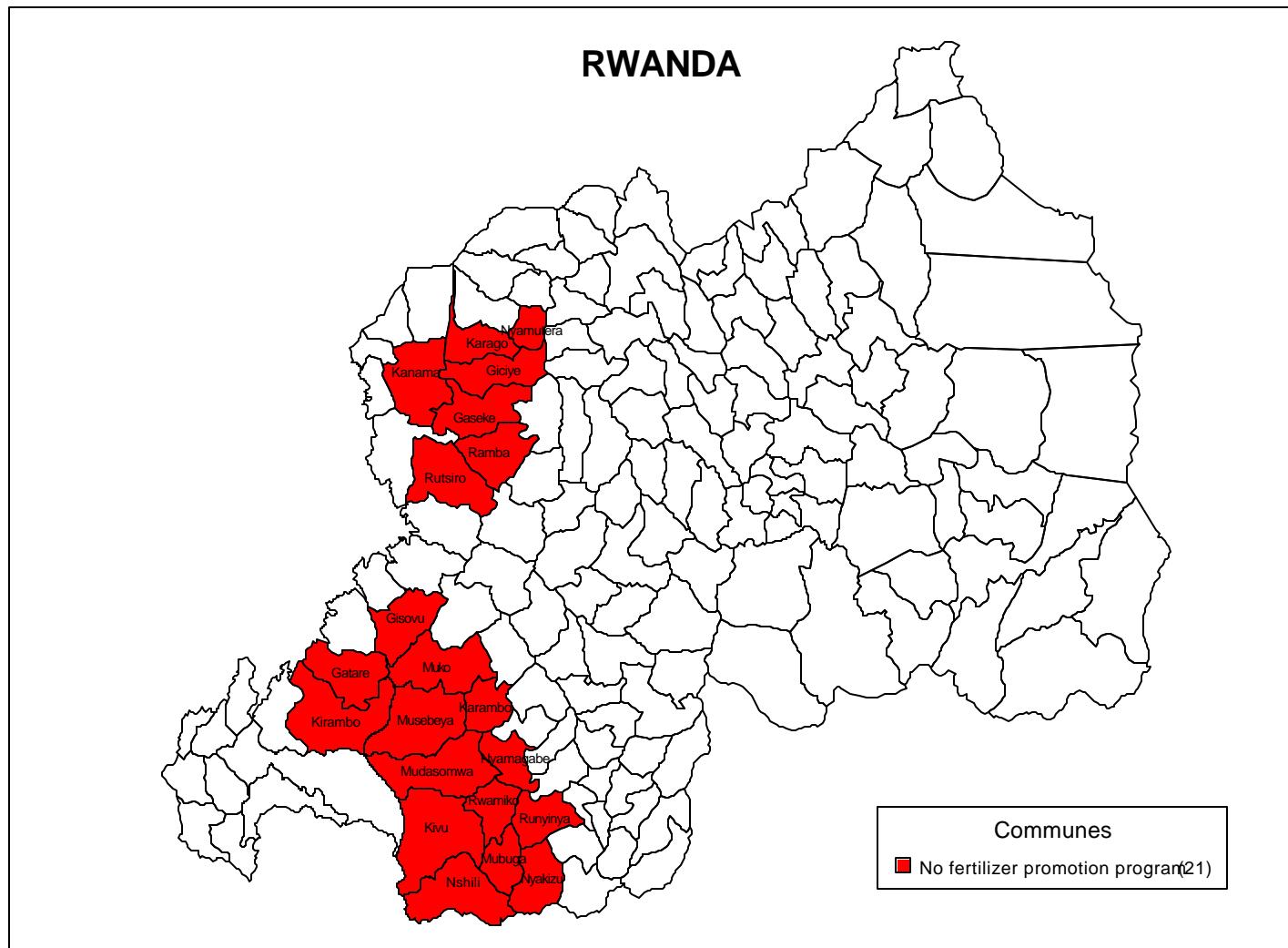


Figure 14. Wheat: Map of Fertilizer Promotion Recommendations for Rwanda

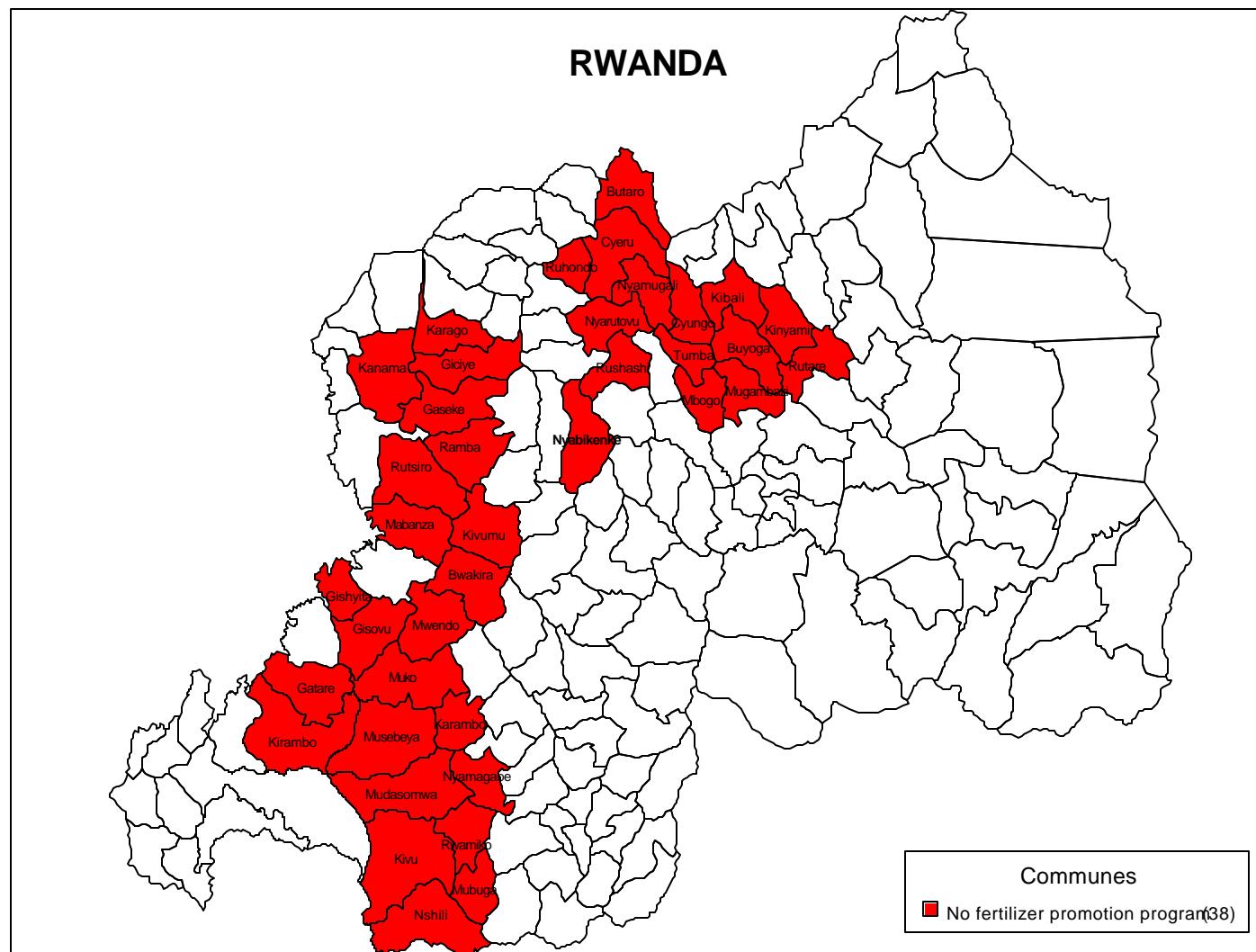
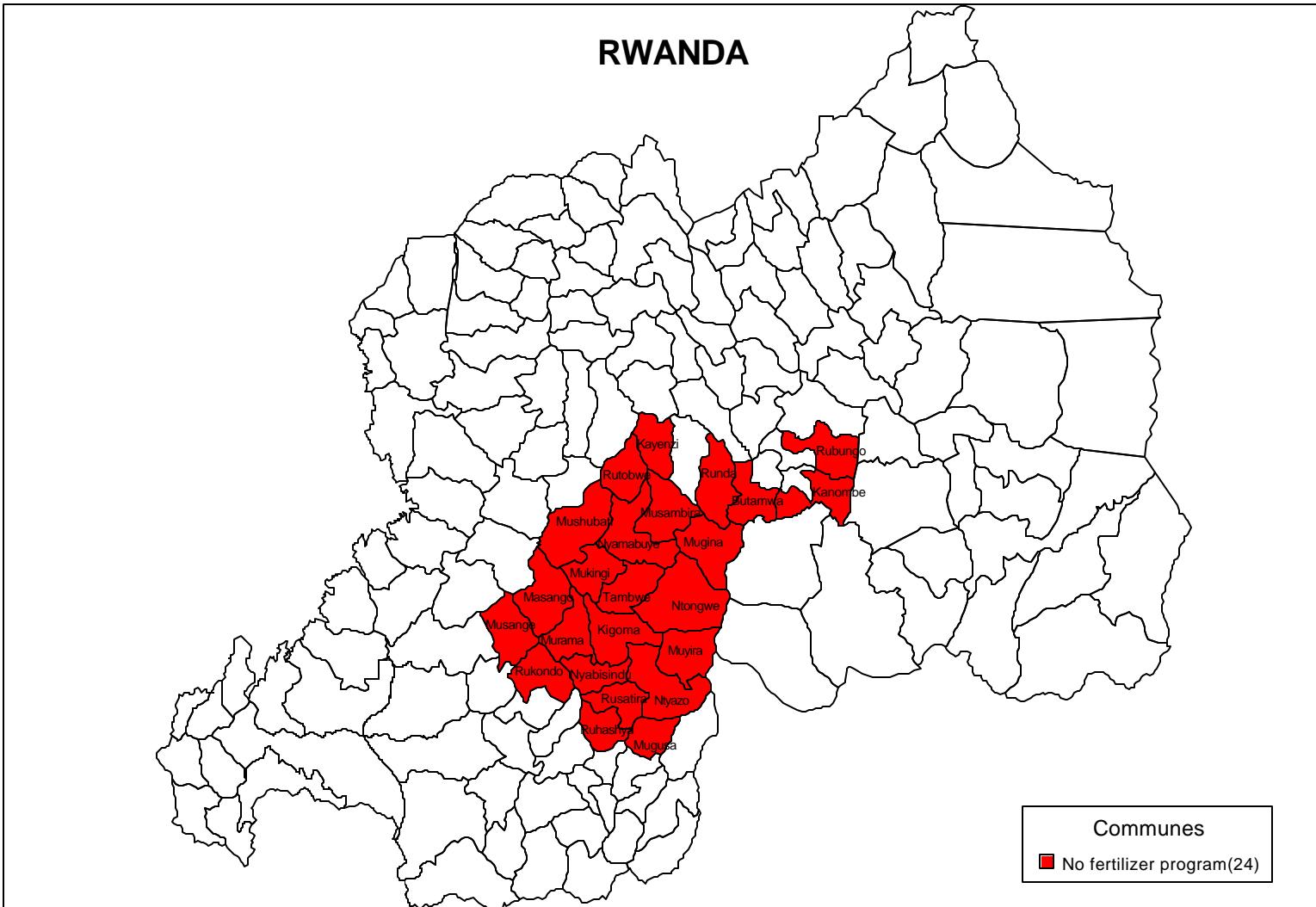


Figure 15. Cassava: Map of Fertilizer Promotion Recommendations for Rwanda



4. TAKING STOCK AND MOVING FORWARD

The information presented in this synthesis represents findings based on an extensive – but not exhaustive – review of fertilizer response literature and data bases available to the FAO and FSRP teams in 1999. The review permitted us to (1) make many concrete recommendations by crop and zone for specific types of fertilizer promotion programs, (2) identify some ‘gray’ areas where information reviewed is inconclusive, and (3) identify some ‘white’ areas for which fertilizer response data have not yet been found.

The Fertilizer Profitability Workshop (MINAGRI/FSRP/FAO, 15 December 1999) permitted an open discussion of the FSRP/FAO preliminary recommendations among a diverse set of individuals currently working on fertilizer issues in Rwanda. The consensus of the workshop participants was that the GOR should adopt a policy of replacing NPK/urea fertilizers with the DAP/urea recommendations that were shown to be more profitable by the FSRP/FAO research. Many of the participants urged that this transition be accompanied by (1) careful monitoring of soil quality (i.e., levels of K, soil organic matter, and acidity in particular) among farmers adopting the DAP/urea recommendations; (2) further basic research on the levels of K, organic matter, and soil acidity throughout Rwanda to evaluate the potential medium- and long-run implications of using DAP in lieu of NPK; and (3) continued efforts to fill in the ‘gray’ and ‘white’ areas of the maps with more solid recommendations.

Based on the workshop participants’ validation of the methods and results of the profitability studies, we outline below some ideas on the possible ‘next steps’ that the GOR and its partners could take as they move forward in transforming the agroeconomic potential for fertilizer use identified in section 3 into high levels of actual fertilizer consumption. We recommend aiming for a new ‘traffic light’ mapping system where within 5 years the green areas represent crop/zone combinations where fertilizer consumption is real rather than potential.

For this to happen, however, requires collaboration and planning among a large group of diverse actors including (but not limited to) farmers, farmers’ associations, extension services (both government and NGO), research institutes, fertilizer importers and distributors, agricultural produce traders and processors, government services and projects. Suggestions on specific tasks that need to be accomplished and ways of getting them done are summarized under four headings below: general organization of fertilizer promotion activities, research and extension activities, market development activities, and the role of government policy.

4.1. General Organization of Fertilizer Promotion Activities

As noted above, the key to successful fertilizer promotion is through coordination of the functions performed by the many actors already involved in the fertilizer subsector. To illustrate the importance of this need for coordination, we use the Fertilizer Profitability Workshop recommendation that efforts to promote DAP/urea fertilizers be accompanied by a system of monitoring. This recommendation raises a multitude of questions. Some of the most obvious are:

- Who should train farmers to use DAP/urea fertilizers?
- Who should do the monitoring (sampling, data collection, analysis, reporting)?
- What are the key items to monitor?
- Who will evaluate monitoring reports and recommend changes if necessary?

- Who will pay for training and monitoring?
- Who will ensure that fertilizer is delivered in a timely and efficient manner?

In many countries extension agents would train farmers to use fertilizer and also do the monitoring (e.g., Ethiopia, Mali, Mozambique), but given that Rwanda has opted for a streamlined extension service it is unlikely that the agronomists now assigned to each commune would have the time and resources to implement a full scale fertilizer training and monitoring program. Other resources in the communes will need to be called into action:

- NGOs are already performing a wide range of extension and monitoring services in many communes;
- DSA (in collaboration with FSRP) is already doing household level survey work in many communes;
- Some fertilizer distributors are already providing credit and output marketing services;
- FAO is currently monitoring fertilizer distributed under their 1994-1999 import program;
- Researchers at ISAR could identify key variables that need monitoring and design appropriate data collection techniques to be implemented by others;
- The agronomy faculty at the university could contribute to the design of the monitoring system and get their students involved in collecting and/or analyzing the data as well as assisting with identifying additional data sources permitting the GOR to develop recommendations for the ‘gray’ and ‘white’ areas of the maps; and
- Core funding from all actors offering to participate could be supplemented with additional funding from government and/or donor-funded projects.

The challenge is to coordinate and facilitate the activities of these diverse actors so that the aggregate effect of all the individual efforts currently underway adds up to more than the sum of the individual parts – overlap and redundancy need to be reduced and complementarities promoted. One way of doing this is to organize monthly meetings of the various stakeholders at the national, prefecture, and commune level – developing strategies and work plans at each level that assign tasks and responsibilities corresponding to each stakeholders interests and capacities. Coordination at the national level might be managed by the Ministry’s Extension Department (supported by the Agricultural and Rural Markets Development Project, ARMDP, funded by the World Bank), at the prefecture level by the DRSA (Direction Régionale de Service Agricole) local administration, and at the commune level by the agronomists.

The point we are making here is that despite the many ‘green lights’ found in the profitability analyses, fertilizer adoption and increased use per hectare is not going to happen without a concerted effort by a wide range of actors. Appropriate coordinating and funding mechanisms must be found to harness the contributions of various actors, making judicious use of their comparative advantages and potential complementarities. The scenario sketched out above is only one of many ways to organize a national fertilizer promotion program. The GOR, in collaboration with its partners, must rapidly develop the most appropriate program for Rwanda, given currently available human, physical, and financial resources.

4.2. Implications for Research and Extension Activities

The profitability study has identified two broad types of fertilizer research that need to be pursued: (1) farm-level monitoring of profitability and impacts on soil quality among those

adopting the FSRP/FAO recommendations and (2) basic research on fertilizer response for crops and zones not well covered by the current study.

The farm-level monitoring should be designed in a manner that permits statistical analysis of both fertilizer response and profitability results (i.e., large sample size, comparison of control and test plots, etc.). Among the factors that one would want to monitor are:

- Changes in levels of K and soil organic matter over time;
- Fertilizer response (kg/ha);
- Profits (v/c ratios);
- Links between level of fertilizer response and production practices (e.g., seeding rates and timing, methods of applying fertilizer, use of anti-erosion techniques, weeding practices, water control, pesticide use);
- Inter-annual and seasonal crop-rotation systems; and
- Inter-annual and seasonal output price variability.

One of the weaknesses of past fertilizer response data is that there is seldom a time dimension permitting one to analyze the inter-annual risk associated with using fertilizer. Developing a data base that follows the same farmers or the same treatments over a period of several years would permit much better estimates of average profitability of fertilizer technologies over time – this type of data can provide useful information for the design of credit programs. As noted in Section 4.1 above, farm-level monitoring of fertilizer response and profitability will require collaboration from a wide range of actors involved in extension, research, and marketing activities.

Filling in the gaps in the basic understanding of fertilizer response for various crops and zones in Rwanda needs to be done in a manner that makes the best possible use of existing data bases. A first step is to rebuild the data bases that were developed during the 1980-1993 period and improve the documentation of these data bases. We suspect that many of the earlier reports for these studies are available in the MINAGRI library, but the archival nature of the document registry system at the library makes it a very time-consuming task to track down the relevant reports. Our recommendation is that faculty and students at the university work with the MINAGRI librarian and the FAO/Kigali librarian in an effort to identify all documents reporting fertilizer response results. Copies of these documents should then be put in a special library and used as the basis for doing additional profitability analyses similar to those conducted by the FSRP/FAO teams. Only in cases where no prior fertilizer response data are found should an effort be made to conduct new fertilizer trials or demonstrations.

In addition to filling in the gaps for specific crops and zones, there is a need to better understand how levels of K and soil organic matter affect fertilizer response – this is an area where the design of past trials prevented one from looking at the interactions. ISAR should be charged with the design and implementation of appropriate studies.

The key challenges with respect to extension are the need to train farmers in the correct use of fertilizers and the need to monitor their progress and revise recommendations if results are less satisfactory than anticipated. To improve the chances of these training and monitoring activities leading to major improvements in agricultural productivity, the extension services should consider some of the following options:

- Limit the number of fertilizer promotion programs to the 2-3 best performing crops per zone;
- Begin with the crops that exhibit strong v/c ratios (>2.5);
- Focus on DAP/urea fertilizers to keep costs down;
- Promote use of anti-erosion structures to ensure efficient use of fertilizers and reduce risk of pollution; and
- Work closely with fertilizer suppliers to ensure that supply approximates demand.

4.3. Implications for Market Development Activities

The GOR's vision for Rwandan agriculture in the 21st century involves transforming what is now a semi-subsistant production environment into a modern, commercial, and highly productive agricultural sector. This means moving from the current situation where farmers produce very little marketable surplus, consume most of what they produce, and remain very poor to a situation characterized by the use of improved technologies that generate farm-level surpluses which can be sold in national, regional, and international markets. None of this will come about if there is not substantial investment made in developing both input and output markets. The Agricultural and Rural Markets Development Project funded by the World Bank will clearly be playing a leading role in assisting various stakeholders make better use of markets.

Private sector actors (farmers, traders, consumers) need to have better access to market information (prices and quantities flowing through different markets) and be better trained in the use of this information. Government has a role to play in collecting and publishing market information. Extension services and NGOs have a role to play in training farmers and their associations how to use the information. Trade and commercial associations have a role to play in improving traders' capacity to use market information. Banks offering credit to farmers and traders also have a stake in market information and analysis as it puts them in a better position to predict debt-carrying capacities.

A major market challenge in the short-run is for fertilizer importers to correctly estimate fertilizer demand. Using available data concerning farm incomes and investment capacity, we have developed a set of three fertilizer demand hypotheses (Table 10). The pessimistic hypothesis assumes that only 20% of agricultural households (1.2 million households in 1999) will have the financial capacity to purchase fertilizer during the 1999-2010 period. The realistic hypothesis assumes that 30% of households (i.e., those classified as being above the poverty line by a 1998 World Bank study) fall into this category. The optimistic hypothesis assumes that on average during the 1999-2010 period 40% of households will be able to purchase fertilizer.

Table 10. Estimation of Effective Demand for Fertilizer: 1999-2010

Year	Type of Hypothesis		
	Pessimistic	Realistic (Tons)	Optimistic
1999	4465	7442	8930
2004	5863	9773	11727
2010	8131	13552	16261

Demand projections reported in Table 10 are based on the following assumptions: Fertilizer consumption increases annually at the rate of the GDP (estimated by GOR at 5.6%); Each purchasing household can spend RwF 2000 per season or 4000 per year (based on MINAGRI national survey data, 1987, and informal survey in Kajevuba, Rwasave and Mwogo cultivated marshlands, 1999).

The 1999 estimates for the realistic hypothesis are quite close to the quantities of fertilizer actually imported for 1999 (sales were at 5811 tons by October 1999 and there appeared to be substantial unmet demand).

If the GOR and its partners move ahead in an aggressive and collaborative manner, we believe it is possible to increase average levels of fertilizer used per hectare substantially. During the recent past, fertilizer consumption has been approximately 2.9 kg/ha of cultivated land. Our estimates suggest that consumption should be able to reach about 8 kg/ha during the next 5 years and even 11 kg/ha by 2010.

4.4. Implications for Sectoral and Macro-economic Policy Design

The role of the government is primarily one of enabling the private sector to produce and market products as efficiently and cost-effectively as possible. Recent measures have been taken by the government to reduce the costs of fertilizer. Among the most important were the removal of taxes (ICHA) and import duties, and establishment of a credit facility for fertilizer importers. Given the relatively small size of the Rwandan fertilizer market at present, it will be important for the government to foster competition in import and marketing activities. This is not an easy task as fertilizer by its very nature tends to exhibit economies of size and scale that mitigate against the development of many small, competitive fertilizer companies. Nevertheless, it will be important to provide safeguards that minimize the chances of a defacto fertilizer import and distribution monopoly developing.

Another import-facilitating role that can be played by government is ensuring that transportation and communications infrastructure is adequate so that (1) fertilizer can be marketed efficiently throughout the entire country and (2) farmers' produce can be moved rapidly from surplus to deficit zones. Both input and output markets must operate efficiently if farmers are to realize the agroeconomic potential of fertilizer described in Section 3.

A final area of policy that might warrant government action is the official promotion of DAP/urea treatments in lieu of using NPK/urea. One of the major results of the profitability analyses presented in this report was the finding that DAP/urea treatments are more profitable (assuming that natural K levels are adequate) than NPK/urea. Official GOR support of this option would be likely to speed up the transition and save farmers substantial amounts of money that would otherwise be spent on unneeded quantities of K included in 17-17-17.

It is recommended that the GOR promote imports of DAP and urea and at the same time fund training programs to help both farmers and traders learn about the proper use of DAP/urea treatments. Introduction of DAP/urea treatments should be facilitated by the fact that there are some zones where DAP is already being used (particularly for beans) and by the fact that some NPK/urea treatments are still profitable (though not the most profitable), permitting a gradual transition from one to the other.

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APPENDIX 1

PRINCIPAL FERTILIZER RESPONSE REFERENCES CONSULTED BY FSRP

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Appendix 3

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