Subsidized Fertilizer in the Sahel: That is the Question

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Abstract

Nutrient depletion concerns researchers and policy makers in the Sahel. A village-level programming model determines the size of fertilizer subsidy necessary to encourage farmers to apply the recommended dosage to their millet fields. Results indicate that subsidies would be extremely costly and less than half the expenditures accrue to the farm-household.

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Subsidized Fertilizer in the Sahel: What is the Cost?

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Introduction

While rainfall in the West African Sahel is low and highly variable, agronomic studies suggest that low soil fertility is the primary limiting factor to agricultural production (van Keulen and Bremen, 1990). Farmers have traditionally used two methods for maintaining soil fertility: fallow and the application of manure. However, increasing population pressure has led to a decrease in the fallow period and manure availability is limited by livestock numbers and the extensive grazing practices. Inorganic fertilizer, including imported chemical fertilizer, appears to be the best means of restoring the nutrient balance, increasing crop yields and raising rural incomes (Bationo, *et al.*, 1998). Use of inorganic fertilizers is extremely low, however, especially since the devaluation of the franc CFA in 1993, and the withdrawal of the state from the marketing channels. In view of continued production shortfalls and fears of land degradation, fertilizer subsidies, long an anathema to economists promoting structural adjustment policies, are once again under consideration (Sanders; Sanders, Shapiro and Ramaswamy). This paper presents the results of a programming model of a typical Sahelian village to determine the subsidy required to encourage the desired utilization of fertilizer and its impact on household and village income.

The West African Sahel is an arid zone that stretches across the continent from Senegal to Sudan. Average rainfall for the zone ranges from 300 to 800 mm per year in a single, three-month period. The quantity of moisture varies greatly from one year to the next, with coefficients of variation around 0.2 to 0.3. The intraseasonal distribution is highly variable as well, with mid-season dry periods often causing severe crop losses. Yet even under these conditions, significant results can be obtained with the use of chemical fertilizer, particularly nitrogen and phosphorus. Fertilizer use in Africa, however, is the lowest in the world, averaging only 5.3 kg/ha in the Sahel (van Reuler and Prins, 1993). More importantly, current farming practices are 'mining' the soil of nutrients, that is, more nutrients are being taken out of the field in grain and crop residues (for animal feed) than are being replaced by fallow, manure or natural replenishment (Bationo, *et al.*, 1998).

There are a number of hypotheses as to why this degradation of a natural resource is occuring. A common explanation is poverty; poverty compels farmers to overexploit their resources and limits their ability to utilize technologies such as fertilizers because of high cash costs or risk aversion. Under this hypothesis, a fertilizer subsidy would permit farmers to make the appropriate investment, lead to an increase in income, and could eventually be removed when farmers have amassed sufficient resources to maintain the investment. Another possibility is that farmers are unaware of the impact of fertilizer and a subsidy would encourage more experimentation. The subsidy could be removed when farmers had become sensitized to the value of using fertilizers. A third hypothesis is that fertilizer use is not cost-effective given the price and availability of the input and the low value of the output. In this case, a fertilizer subsidy might encourage greater use, but removal of the subsidy would simply result in farmers returning to their traditional practices[1].

The goal of this paper is to determine if a subsidy is necessary to encourage a profit-maximizing farmer to use fertilizer on his or her millet fields and, if so, of what amount. If fertilizer use is profitable, we would find support for the first hypotheses that suggest market constraints or lack of knowledge is the primary reason for low fertilizer use. Temporary fertilizer subsidies might then be an appropriate policy measure. If, however, fertilizer use is found to be constrained by low returns, then we must consider carefully the costs of any

[1] Inappropriate tenure systems that do not provide incentives for investments in land improvements are often blamed, but inorganic fertilizer is not a long-term investment but a way of maintaining the immediate nutrient

subsidy program that may not be effective in the long term.

Methodology and Data

We use a village-level non-linear programming model to examine the crop and livestock management patterns of a typical Sahelian village. The primary source for the data is a multi-scale land-use characterization carried out as part of an on-going project to develop a multi-scale decision support system. The data consist of detailed biophysical descriptions, including types of soil distinguished by local cultivators, production systems and socio-economic data. Households are grouped into three categories determined by the amount of land and labor available. Household demand for basic consumption goods are based on FAO requirements. Since farmers are not currently using fertilizer on their fields, on-station trial results were used. However, since farmers may lack complementary inputs, and the interaction between manure use and fertilizer has not been examined, we reduce the expected impact of fertilizer by 20 percent.

The key village with respect to this paper is Lagassagou, near Bankass, Mali in the region of Mopti. Household needs and resources are shown in Table 1. The village is located on a sandy plain to the south of the Dogon plateau and is a primary millet producing region. There are 33 production units in the village which range from single households to groups of households. Infrastructure is limited. There are two markets within walking distance of the village, but transport of goods must be done by hand or by cart. Within the village, exchange is primarily limited to services: labor or transport. Most other goods are exchanged at the weekly markets. Labor can occasionally be exchanged with producers in other villages.

Fields are distinguished by distance from the village. *Lara* fields are close to the household while fields far from the village are called *baracoum*. The distance increases labor

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balance. Additions of organic material, such as manure, have longer lasting effects and are being practiced.

time for agricultural activities, particularly for the application of organic material. Animals are usually kept near the household compound at night and the manure deposited directly on the fields. To apply significant quantities of manure to the *baracoum* requires collecting the manure from around the compound and transporting it to the far fields. For this reason, the general pattern is that the *lara* is cultivated almost continually while the *baracoum* is periodically left fallow. There is little capital equipment used. The light, sandy soils do not require plowing; in fact, plowing can increase nutrient losses. The primary equipment are carts for transport.

The main crop of the region is millet, which is grown for both home consumption and for sale. Sorghum is occasionally planted in small depressions where water collects. Groundnuts and cowpea are cultivated as cash crops. The residue is also valuable as livestock feed. Fonio, sorrel and Bambara groundnut are minor crops. The cropping season begins in June or July with the rainy season. Harvest occurs in November and December. There is frequently significant out-migration during the dry season.

The livestock system is equally low input. Herds consist of cattle and small ruminants, plus donkeys and horses for traction. Animals primarily graze the areas left fallow and the crop residue left in the fields. During the rainy season, cattle are usually entrusted to local herders who take them to pastures away from the cultivated areas, returning in about four months. Generally a few sheep are kept in a more intensive fattening regime and are sold on the local market for the Tabaski holiday which this past year fell in March.

The major improvement of this model over previous efforts (Shapiro and Sanders, 1998; Coulibaly, *et al*., 1998) is that the crop and livestock systems are modeled together and compete for some of the same resources, while also providing intermediate inputs to the other system. Migration opportunities, which compete for family labor time, are also included. Cash investments will therefore flow to the activity with the highest return, not merely a positive return. Sales of livestock, to fund purchases of monetary inputs, for example, must weigh future losses in terms of meat, milk, and manure production against the benefits of increased grain production.

Results and Discussion

The results of the base model are given in Table 2, showing area cultivated and fertilizer application. The model still requires some adjustment. It greatly overstates the area cultivated in groundnuts. This may be due to considerations of risk, which are not considered in this model. Millet is more tolerant of drought, including dry periods within the growing season. There could also be an element of market risk. Farmers may be unwilling to rely on the market to supply their food needs. Another consideration is that groundnuts are grown for the residue which is used as forage. The model suggests that the production units will be primarily engaged in the fattening of cattle and sheep, purchasing animals when there is forage and selling them at the beginning of the dry season. What is not taken into account is that restocking every year is only possible if there are animals available.

However, the results are suggestive, particularly those for production unit B, which most closely resembles the actual situation. A majority of land, particularly in the outer fields, is cultivated in millet with no fertilizer. Manure in the outer fields is also limited and the fallow system is used to maintain soil fertility. Income is approximately $1200 per person per year; low, but still much higher than is observed. The other types of production units do use fertilizer, which suggests that it is economically viable and could be more so if farmers were able to learn proper management techniques or to invest in the necessary complementary inputs that would provide them with yields more similar to those obtained by researchers. A major impediment appears to be the cost of transporting the fertilizer from the market to the village. Fertilizer cost is not high in absolute terms, about $0.43 per kilogram. However, transport costs, including the cost of a cart and labor time, are over 30% of the price leaving a shadow price of $0.64 per kilogram.

A fertilizer subsidy could thus be seen to encourage farmers to experiment with using fertilizer, increasing their management skills and increasing the returns. However, as shown in Table 3, the actual impact of a subsidy may be quite limited. For production units of type B, even a 40% reduction in price only results in an application rate of 17.5 kg/ha on millet fields and increases application on groundnuts to 21.7 kg/ha. This is still far below the recommended levels. Even more surprising is that the subsidy has no measurable impact of household income, despite an expenditure of about $52 per household. This means that if farmers need complementary inputs, such as additional labor for weeding or additional manure to maintain levels of organic matter, that the subsidy does not provide additional revenues from which to make the necessary investments.

In fact, the benefits accrue to the larger households that are more involved in cash cropping, production units A. This type of household is probably more representative of households in the wetter, southern regions of West Africa and highlight an additional problem with subsidies. Even were the subsidy targeted to the millet producing areas, there would be significant leakage to other areas. Given that most of West Africa has a common currency, the West African Franc (CFA), there could even be significant international leakage of benefits to the coastal countries like Côte d'Ivoire.

Finally, the costs of a subsidy could be very high. The results of the model suggest that the direct costs, in terms of the actual subsidy, would be approximately $7.50 per ha cultivated. The target area of millet production is approximately 10 million hectares (ICRISAT, 1996). This cost of $75 million dollars does not include administration costs or costs of leakage to other areas, which could also be significant. Given that the impact appears so limited, one has to question whether the expense could be justified for the cash-poor governments of the region.

Conclusion

This paper has presented the results of a programming model to determine the impact of a fertilizer subsidy on a typical West African village. It is found that the impact is minimal, both in terms of additional fertilizer application and increased household income. Many of the benefits will accrue to producers in cash-crop producing areas that are already using fertilizer. The costs of a fertilizer program will be high, and higher still if one takes into account administrative costs. The effectiveness of such a program, both for improving soil fertility management and household income, is doubtful.

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Table 1. Household and village requirements and resources.

	UP(A)	UP(B)	UP(C)	Village
Population	39	10	5	735
Monthly food requirements				
cereal (kg)	585	150	75	11025
milk (l)	19.5	5.0	2.5	367.5
Resources				
labor	21	5	3	393
land (ha)	19.7	14.9	4.9	503.7
lara	3.0	2.9	1.0	85.8
baracoum	16.7	12.0	3.9	417.9
Production units (UP)	15	12	6	33

Table 2. Base results, area cultivated and fertilizer application.

	UP(A)	UP(B)	UP(C)	Total
lara				
groundnut (ha)	3.0	2.3	0.9	78.3
fertilizer (kg/ha)	65	80	80	
baracoum				
millet (ha)	0.7	3.3	0.8	54.0
fertilizer (kg/ha)	15	0	40	
groundnut (ha)	9.5	2.6	1.3	180.7
fertilizer (kg/ha)	40	13.4	40	
total fertilizer (kg)	585	220	156	12,345
income ($USD)	83,775	11,809	6,533	

Table 3. Results of subsidy ($0.715/kg), area cultivated and fertilizer application.

	UP(A)	UP(B)	UP(C)	Total
lara				
groundnut (ha)	3.0	2.4	0.9	78.8
fertilizer (kg/ha)	65	80	85.4	
cowpea (ha)			0.1	0.4
fertilizer (kg/ha)			120	
baracoum				
millet (ha)	0.7	3.8	1.0	60.9
fertilizer (kg/ha)	21.9	17.5	40	
groundnut (ha)	9.5	2.1	1.1	174.2
fertilizer (kg/ha)	40	21.7	40	
total fertilizer (kg)	589	299	171	13,452
cost ($USD)	103	52	30	2,360
Δ income ($USD)	156	0	0	