Staff Paper

Evaluating Measures to Improve Agricultural Input Use

by
Eric W. Crawford and Valerie A. Kelly

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Department of Agricultural Economics
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan 48824

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crawfor5@pilot.msu.edu

Abstract

This paper provides guidelines to assist policymakers and analysts in (1) identifying promising public and private actions for promoting agricultural intensification by improving the availability and profitability of agricultural inputs; and (2) evaluating the relative costs and benefits of alternative actions. The guidelines are illustrated by reference to a study of phosphate fertilizer promotion in Mali originally conducted by IFDC researchers.

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1. Background

Intensification of agriculture through increased input use is crucial for alleviating poverty, attaining food security, and protecting the environment in Africa (Reardon, Crawford, and Kelly, 1995; Kelly et al., 1999; FAO, 2001). Farmers must increase their use of improved seeds, fertilizers, and other inputs if intensification is to take place. The same applies to improved technologies for livestock production. The challenge for policy makers and analysts is to identify ways of promoting intensification that will be cost-effective and sustainable for the private sector (e.g., farmers, input suppliers, consumers of agricultural products) and the government. The Asian Green Revolution provides many examples of countries having achieved agricultural intensification through a wide range of government-supported research, extension, and market activities.

Progress on agricultural intensification in Africa appears to be moving more slowly than in Asia. For example, it has been more than a decade since scientists began warning farmers and governments about a serious decline in Africa's soil fertility. This decline threatens agricultural productivity and environmental stability, yet little concrete progress has been made in addressing the problem. Many governments have developed soil fertility management plans designed to stop the decline in soil fertility through increased use of fertilizers (both organic and inorganic) and promotion of techniques to control soil erosion (Weight and Kelly, 1999; Sanchez et al., 1997). However, moving from the design of these soil fertility management plans to the implementation stage has been difficult. In many cases, limited financial resources and inadequate information on the relative costs and benefits (both private and social) of alternative programs have made it difficult for governments to identify priority areas for implementation.

2. Objectives

This paper provides guidelines to assist African policymakers and analysts in (1) identifying promising public and private actions for promoting agricultural intensification (particularly actions that improve the availability and profitability of agricultural inputs); and (2) evaluating the relative costs and benefits of alternative actions. Although the guidelines presented here are relevant for the analysis of a broad range of agricultural policy issues, the discussion and illustrations focus on soil fertility issues and actions to promote fertilizer adoption because they are currently in the forefront of agricultural intensification debates in Africa.

3. Conceptual Framework and Organization

The paper outlines a general benefit-cost analysis approach, within an input and output marketing systems perspective. Multiple objectives and performance criteria are taken into account in addition to the standard criteria of financial (private) and economic (social) profitability.

In using a benefit-cost approach, the **economist** focuses on net income at the individual and the national level. Economic impact is defined as net increases in national income, i.e., real productivity increases that occur when the value of output (yield times price) rises by more than the value of inputs used. The stream of such productivity increases over time is discounted and expressed in present value terms. If public benefits (also refereed to as economic or social benefits) exceed private benefits (also referred to as individual or financial benefits), subsidies may be appropriate to allow full public benefits to be realized.

The perspective of other disciplines evaluating the pros and cons of alternative programs to promote agricultural intensification would be different from the economist's perspective presented in the previous paragraph. It is important for an analyst to understand these different perspectives and attempt to reconcile them. For example, an a**gronomist or soil scientist** might focus on nutrient balances and other physical measures of soil fertility. A particular input or input promotion program might be judged by its ability to maintain (or increase) soil nutrient stocks and levels of soil organic matter. The benefits of stocking nutrients and organic matter in the soil might be taken as given and nutrient stocks might be valued using the prevailing cost of N, P, and K fertilizers.[1] Unlike the economist, the agronomist or soil scientist would not necessarily value the nutrient stocks in terms of future productivity (e.g., the future yield impact due to changes in physical measures of soil fertility).

An **environmentalist** might have a third perspective, focusing on resource and ecosystem preservation. As with the agronomist or soil scientist, impact might be evaluated exclusively in terms of physical indicators, without translating them into economic terms or expressing them in present value terms. Some environmental resources may be considered to have intrinsic benefits for which quantification and monetary valuation are inappropriate (e.g., preservation of certain species, or of culturally significant sites).

The main differences among these three perspectives, then, concern the types of costs and benefits that are counted, the degree to which the contribution to future productivity (e.g., yields) is quantified and valued in monetary terms, and the extent to which the concept of discounting future benefits (i.e., giving future benefits less value than present benefits) is incorporated.

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[1]Alternatively, depletion of nutrient stocks may be taken into account as a cost and valued at prevailing fertilizer prices.

The rest of this paper is divided into two sections. Section 4 outlines a general benefit-cost (b-c) approach that can be used to evaluate alternative actions for promoting agricultural intensification through increased use of improved inputs. In this section we describe each of the steps that an analyst must complete when conducting a b-c analysis, highlighting some of the more difficult data and valuation issues. In Section 5 we present a case study b-c analysis to illustrate how the analytical tools described in Section 4 have been applied to evaluate input promotion programs in Africa. The general benefit-cost approach presented in this paper is an economist's approach, but as we work through the various analytical steps and the case study, we discuss methods that the economist can use to take into account the perspective of other disciplines and the types of information that other disciplines must make available to economists if b-c analyses are to be improved.

4. A General Benefit-Cost Approach

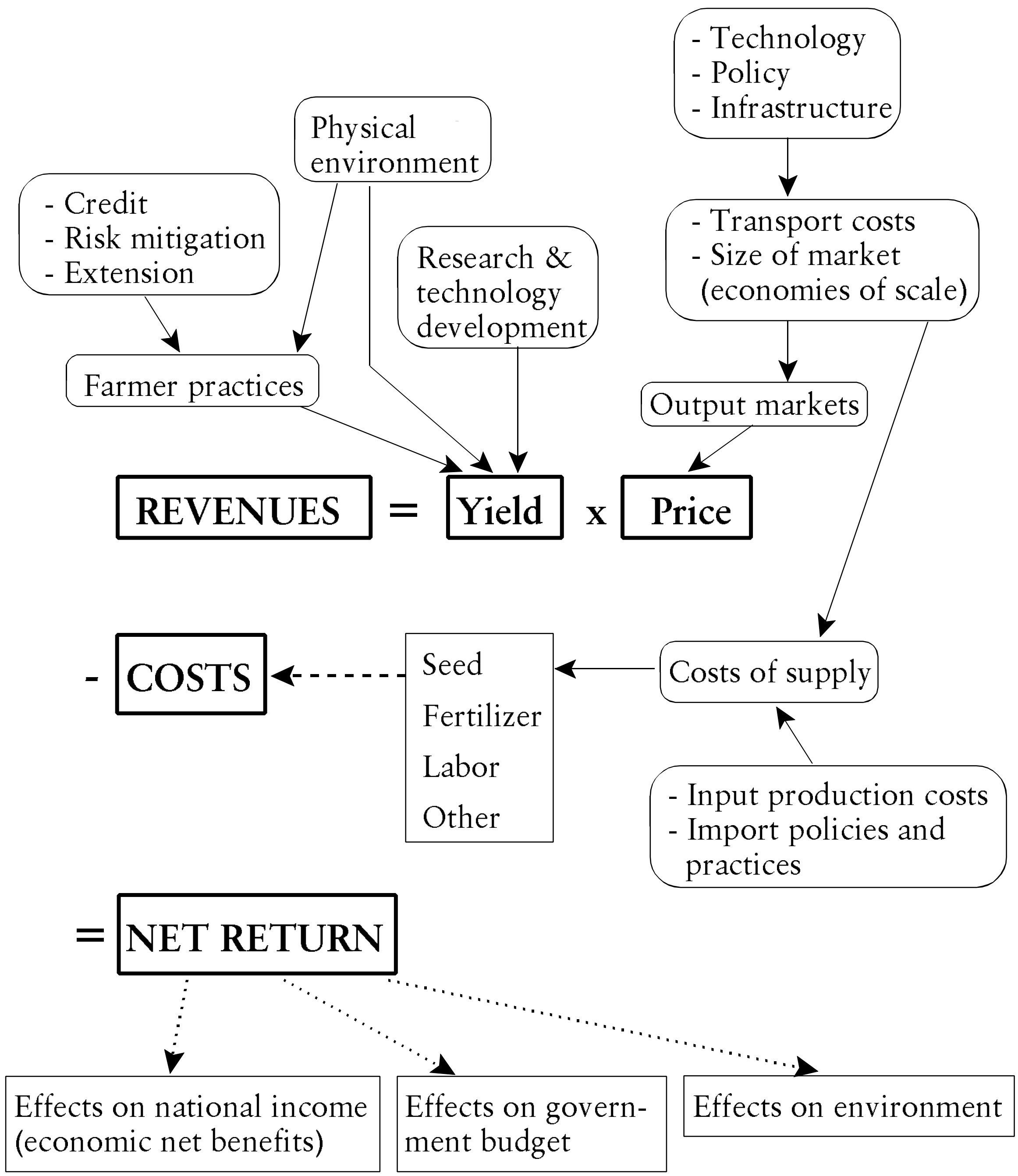
4.1 *Selection of options to evaluate*

There are many ways of improving agricultural input use. Choosing a particular set of policy and/or project interventions to evaluate requires first defining the universe of potentially relevant options. This is not a trivial issue, since analysis of an incomplete or biased set of options may be misleading or useless. Identifying the set of options also requires (a) agreement on the goal (types of benefits) being pursued, and (b) an accurate understanding of the factors that affect the benefits.[2] In identifying interventions to promote input use an analyst would be looking for actions that increase the profitability of inputs either by increasing the value of output (higher price or yield), or by reducing the cost of inputs. As indicated in Figure 1, interventions at all levels of the input and output marketing system can influence the value of output and the costs of inputs, so the search for potential interventions should be wide-reaching.

Once the universe of relevant options has been defined, it must be narrowed down to a subset for which analysis is both feasible and desirable. Such a decision should obviously be a function of the goals of the decision maker(s) for whom the study is conducted. This narrowing down of options should draw on what we already know about the types of projects, policies, and programs that have been successful in Africa and elsewhere during the past.

[2]There will be more discussion in the case study section on identifying goals and factors influencing benefits.

Figure 1. Farm-Level Net Returns from Improved Technology: Components, Determinants, and Aggregate Impacts.



The following insights summarize a number of key relationships that have been well documented in the input adoption and agricultural marketing literature:

A. Input use can be increased through financial and other incentives (e.g., fertilizer subsidies), but this is often unsustainable from a government budgetary perspective (Reardon, Crawford, and Kelly, 1995; Donovan, 1996; Bumb and Baanante, 1996).

B. Vertically integrated input and output markets are associated with high levels of input use that are usually, if not always, driven by an industrial or high-value crop such as cotton, tea, or sugar cane. Despite the past success of this model, the monopolistic nature of the output markets is increasingly causing concern about the long-run sustainability and desirability of such arrangements (Tschirley et al., 1999; Kelly et al., 1999; Reardon et al., 1996; IFDC 1999).

C. Related to the above, there are potential synergies between cash and food crop production (increased use of fertilizer on cash crops can contribute positively to food crop productivity) (Dioné, 1989; Jayne, 1994; Govereh and Jayne, 1999).

D. Constraints on the profitability of private input dealers should not be ignored (risk; need for working capital). This is especially true for fertilizer (Crawford et al., 1987; Barrett, 1997; Poulton, Dorward, and Kydd, 1998; IFDC, 1999).

E. The attractiveness of inputs to farmers depends on:[3]

    1. Willingness to invest, a function of the profitability of input investments relative to the profitability of other farm and non-farm investments available to the farmer;

    2. Ability to invest (availability of cash, labor, land, etc.);

    3. Enabling institutions and policies (land tenure, credit programs, contract enforcement, etc.).

F. Government-run fertilizer distribution programs are plagued by chronic problems that will recur unless something explicit is done to prevent them. These include:

    1. Late delivery (often a result of foot-dragging stemming from disputes between government, manufacturers, and distributors over risk-sharing and financing) (Crawford et al., 1987);

    2. Inappropriate formulas (N,P,K mixture)—sometimes a result of deals made between government, donors, and commercial suppliers (Howard et al., 1998);

[3]See Reardon, Crawford, and Kelly (1995); Yanggen et al. (1998); and Gordon (2000) for more discussion of this issue.

3. Poor quality control (Kelly et al., 1998).

G. Combining inorganic fertilizer with organic inputs and/or liming can mitigate the tendency of inorganic fertilizers to increase soil acidity and increase the productive efficiency of inorganic fertilizers (Weight and Kelly, 1999).

4.2 *Defining and enumerating benefits and costs*

4.2.1 Objectives

The objectives of the proposed intervention—let's now call it a project—must be identified explicitly. This is partly because benefits and costs are defined in relation to the objectives being pursued, and partly to ensure that the design of the project is consistent with stated objectives.

4.2.2 Numéraire

A numéraire is needed for expressing benefits and costs in terms of a common denominator or unit of account. The definition of the numéraire also reflects the perspective to be used in assessing benefits and costs. Let us look at these two aspects of the numéraire in reverse order.

4.2.2.1 Perspective

Questions of perspective or level of the analysis include:

– should the project be evaluated from the perspective of individual participants or entities? This is the perspective implied by *financial analysis*, which focuses on financial profitability and budgetary impacts for government, and the distribution of benefits and costs among the major stakeholders.

– should the project be evaluated from the perspective of the national economy? This is the perspective of *economic analysis*. Analyzing profitability for the farmer does not require consideration of external ("downstream") impacts. Analyzing profitability at the national level does. Although this approach typically focuses on economic (sometimes called "social") profitability, an even broader (though still national-level) perspective may be called for if the project is supposed to address environmental, social, or political objectives that cannot be expressed in terms of impacts on "economic efficiency" or national income.

– should the project be evaluated from a perspective beyond the national level, i.e., to take into account potential impacts at a multi-country or even global level (e.g., environmental impacts resulting from flooding and erosion (Nepal/India), fires (Indonesia), deforestation (reduced capacity for carbon sequestration), industrial activity (release of greenhouse gases) etc.

– should the project be evaluated from the perspective of future generations as well as the present one? This is the issue of *sustainability* and inter-generational equity.

4.2.2.2 Common denominator

The common denominator is usually a monetary unit, which embodies a currency (domestic or foreign) and a price level (financial or economic). Projects are usually evaluated in the currency of the country implementing the project. The financial analysis uses market prices actually paid or received by project participants. The economic analysis uses prices that reflect opportunity cost, which may be expressed either at the domestic price level or at the "border" price level. The former approach values traded goods at their import or export prices converted to domestic currency at the shadow (economic) exchange rate, and nontraded goods at their domestic market prices adjusted for distortions (e.g., removing the effects of taxes and subsidies). The latter approach values traded goods at their import or export prices converted to domestic currency at the official exchange rate, with conversion factors used to express nontraded goods in border price equivalents (Belli et al., 2001, 37-38).

Occasionally, b-c analysis may be conducted on a per-hectare basis, either to simplify the analysis or because of data limitations. More commonly, benefits and costs are aggregated at the farm or firm level (especially for financial analysis) and at the project level (especially for economic analysis).

4.2.3 Enumeration of benefits and costs

All significant categories of benefits and costs of alternative input promotion strategies should be considered. In most cases, this will include economic (or "social") as well as financial benefits and costs. As an example, see table 1, which shows an illustrative set of benefits and costs for three alternative investments designed to promote fertilizer use—a project to promote application of phosphate rock, fertilizer subsidies, and road improvement to reduce input and output marketing costs.

It is important to do a complete enumeration of the costs of input promotion. Neglect of full costs during project design and evaluation is a prime reason for the ultimate failure of many past actions. Many agricultural technologies or input promotion projects look good if you ignore some of their costs (e.g., the cost of extending the technology or providing complementary services such as credit, marketing information or infrastructure), or if you do not evaluate the long-run sustainability of such technologies or projects realistically.

Sometimes it is a challenge to determine whether a particular project impact is a benefit or a cost, and how to incorporate it concretely in the analysis. Two common problems of this type are foreign exchange savings and employment creation. Foreign exchange savings are clearly a benefit, but are incorporated indirectly through the shadow prices used for imports or exports (discussed below). Employment creation is more tricky. In standard project analysis, which focuses on the objective of increasing the net value of output at the national level, "increased employment" means increased labor use within the project, which is counted as a cost not a benefit. The main issue is how to put an economic value on the cost of labor, which may be less than the financial value (discussed further in section 4.3.1 below). The benefit associated with increased labor use is the value of output produced by the additional labor.

Table 1. Structure of Benefits and Costs for Selected Input Improvement Options

Category	Phosphate Rock Project	Fertilizer Subsidies	Road Improvement	Notes on Benefit or Cost Items
Benefits				
↑ Value of output	✔	✔	✔	From increased yield or price; foreign exchange savings incorporated here
↑ Consumer/producer surplus	✔	✔	✔	From lower product prices for consumers or lower input costs to producers
↑ Indirect income effects	✔	✔	✔	Increased incomes due to backward and forward linkages (transporters, input suppliers, agricultural commodity processors, etc.), or employment of unemployed labor (a "benefit" which could be shown on the cost side as a low economic cost of labor)
↑ Carbon sequestration	✔	✔	negative effect possible	Carbon sequestration reduces greenhouse gas emissions, thus reducing the costs of global warming.
↑ Nutrition	✔	✔		Increased output improves access to food.
↓ Erosion	✔	✔	negative effect possible	Reduced costs of soil degradation, flooding, and negative impacts on downstream productive or consumptive uses of water.
↓ Deforestation	✔	✔	negative effect possible	Reduced biodiversity losses; may overlap erosion and carbon sequestration benefit categories.
↓ Use of marginal lands	✔	✔	negative effect possible	Increased land productivity decreases need to clear marginal lands for agriculture
Intangible benefits	✔	✔	✔	Improved food security; poverty reduction, improved income distribution
Costs				
↑ Fertilizer cost	✔	✔	✔	From fertilizer manufacture.
↑ Labor & equipment costs	✔	✔	✔	For fertilizer distribution and application.
↑ Pollution from fertilizer use	✔	✔		Nitrate or phosphate pollution; possible pollution from heavy metals such as cadmium from phosphate fertilizer.
↑ Pollution from fertilizer manufacturing	✔	✔		Manufacture of ground or partially acidulated phosphate rock would pollute less than wet-process phosphate fertilizer
Government budget/fiscal costs	✔	✔	✔	Impact (+/-) of option on government budget; economic cost of taxes to fund programs.
Investment in infrastructure			✔	To reduce transport, handling, other physical transaction costs.
Investment in mkt. info. system	✔	✔		To improve coordination of input supply and demand.
Project administration costs	✔		✔	

One can also consider employment creation as a second objective, in addition to the basic objective of increasing national income. Indicators of employment increases could then be reported along with net national income benefits for purposes of evaluating alternative projects. However, evaluating projects in terms of multiple objectives is not straightforward, since project A may look better than project B on objective 1, but B may look better than A on objective 2. Project selection then requires either subjective evaluation of trade-offs among objectives, or the use of preference weights on the different objectives in order to come up with an aggregate index of project impact.

4.2.4 Quantifying benefits and costs

Quantifying benefits and costs (determining their magnitude) requires the expertise of technical scientists and economists, so that the physical effects of a particular action (e.g., increased soil organic matter) can be translated into a measure of output (e.g., increased yield) that can be valued in economic terms. Long-run and environmental impacts are particularly hard to quantify. Without some way of translating those physical effects into a measure of output, their economic impact cannot be evaluated.

4.2.5 Identifying incremental effects

The analysis of interventions to improve soil fertility or agricultural input use must be structured so as to identify the impact of the intervention over and above what would have happened in the absence of the intervention. Using a “with” vs. “without” comparison to identify these incremental effects is essential to avoid over- or underestimation of impacts. Integrity is required to resist the temptation to attribute benefits to one’s project that really result from other actions or trends within the economy!

4.3 *Valuing benefits and costs*

4.3.1 Financial (private) vs. economic (public or “social”) prices

In financial analysis, benefits and costs are valued in terms of market prices, those paid or received by the project’s participants. Outputs that are consumed by the family rather than being sold, or inputs (e.g., seed) that come from the family’s reserves rather than being purchased, are given an imputed value based on the prevailing market price for sale or purchase. In economic analysis, valuation is based on opportunity cost, i.e., the value of the good or service in its next best use. In many cases, the opportunity cost of an item differs from its market price, e.g., because of public intervention in the market (taxes, subsidies, marketing controls). An example is labor. In the economic analysis, the opportunity cost of labor is the economic value of output forgone when labor is moved from its without-project occupation to work on the project. In various cases, such as underemployment, the economic cost of labor is less than the market wage rate. It may be close to zero for labor that would be unemployed without the project. In this situation, one might say that reducing underemployment is a benefit because increased economic output is obtained at a relatively low economic cost.

Another example is the valuation of foreign exchange savings. These benefits are incorporated indirectly by the use of shadow prices for imports or exports that incorporate the foreign exchange premium, which reflects the extent to which the domestic currency is considered overvalued due to various government interventions or market imperfections.

In the case of environmental effects, there may be no market price at all, so that the value to producers or consumers must be estimated indirectly (Dixon et al., 1994). An extensive literature exists on concepts and methods of determining economic prices (Gittinger, 1982; Belli et al., 2001). In cases where the margin of error in estimating the physical effects of soil fertility or input promotion projects is large, rough estimates of the economic prices of these effects makes more sense than minutely refined estimates.

4.3.2 <u>Intangibles, and valuing the "invaluable"</u>

By definition, intangible impacts are impossible to quantify or to value. Significant effects of this type should nonetheless be highlighted in the analysis so that they can be considered by the decision maker concerned. Efforts of economists to place values on such effects sometimes meet opposition from noneconomists. The debates that ensue should not be avoided, since they help clarify people's preferences and lead to improvements in analytical techniques that ultimately contribute to better public decisions. An example is the use of contingent valuation, a technique for eliciting the economic values people put or might put on goods or services (often environmental) for which there is currently no market that generates an explicit price.

4.3.3 <u>Sustainability</u>

Long-run impacts are difficult to handle, especially those which are likely to be irreversible. Issues here include the definition and treatment of sustainability as an objective to be considered along with profitability (Pearce, 1989); the appropriate discount rate to use in economic analysis, or whether to discount future benefits at all (Hanley and Spash, 1993); and the treatment of irreversible impacts such as species extinction (Barbier, Markandya, and Pearce, 1990). All these issues are germane to the evaluation of soil fertility and input use improvement projects, since they involve, at least indirectly, potentially significant changes in land use patterns. As with intangibles, these effects should be evaluated qualitatively and reported for the decision maker's consideration.

4.4 *Gainers and losers*

Typically one wants to look at not only the aggregate totals of benefits and costs, but also at how they are distributed among various groups in society. Implicitly, this means adding a second, distributional (or equity) objective to the basic objective of economic efficiency (or net gains in national income). The simplest approach is to present in tabular form the distribution of financial benefits and costs (those actually received or paid) across the major groups of interest (income classes, regions, consumers / producers / government, etc.). Analyzing the incidence of benefits and costs is important not only because one cares about equity, but also because the sustainability of the project depends in part on how benefits and costs are distributed. A project which benefits just a few at the expense of many (or at the expense of powerful stakeholders), is unlikely to enjoy a long life.

4.5 *Treatment of uncertainty*

The issues involving the treatment of uncertainty are not significantly different for soil fertility and input use improvement projects than they are for other projects. Some impacts may be difficult to predict with confidence, especially over the long run, but that problem and how to handle it are not unique. Sensitivity analysis can be done to test the robustness of the profitability calculation. Alternative assumptions about yields, output prices, and the cost of major inputs (e.g., labor) are usually the most useful to analyze. If more thorough analysis of price and/or yield variability is desired, computer software such as @Risk[4] (an add-in for Lotus 1-2-3 or Microsoft Excel) makes sophisticated risk analysis relatively easy to conduct.

4.6 *Data requirements*

Two major questions would need to be answered in an empirical b-c analysis. First, what data/information is needed to predict:

A. The impact of each alternative (the "with" scenario);

B. Trends likely to occur if no action is taken (the "without" scenario)?

Second, what information is not now available, and would have to be collected? In both cases, a key challenge will be to find information on, or proxies for, the output or yield effects of soil fertility improvement or input promotion programs. Another challenge, particularly for the evaluation of input promotion programs, is to predict changes in marketing and distribution costs over time in response to increased volume of business. To what extent can economies of scale be realized in input production and distribution? Another challenge is dealing with the potential impact of widespread input adoption on aggregate production and output prices (i.e., is effective demand for agricultural products of interest strong and increasing?).

5. Case Study: *Ex Ante* Evaluation of the Benefits and Costs of Using Local Rock Phosphates in Mali

We turn now to an example of an *ex ante* benefit-cost study of a program to promote the use of locally produced phosphate rock fertilizers in Mali. The study was conducted by the International Fertilizer Development Center (IFDC), and reported in Henao and Baanante (1999). We summarize the proposed phosphate program and discuss the IFDC study, and then lay out an alternative framework for conducting the same analysis. Among the analytical issues which the authors of the study attempt to address are: (1) evaluation of global environmental benefits such as carbon sequestration, (2) dealing with weaknesses in technical

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[4]Palisade Corporation, 31 Decker Road, Newfield, NY 14867; http://www.palisade.com

data on yield response, and (3) factoring in the potential for foreign exchange savings and employment benefits resulting from increased use of local phosphate rock.

5.1 *The problem*

Although most SSA soils are deficient in phosphate, several African countries (e.g., Burkina Faso, Zimbabwe, Senegal, Togo, Madagascar, and Mali) have relatively large deposits of phosphates which could possibly be developed to provide local farmers with a reliable supply of P fertilizers at a lower cost than the products currently being imported (e.g., SSP, TSP, MAP, and DAP). During the 1990s, four countries (Zimbabwe, Madagascar, Burkina Faso, and Mali) undertook studies to evaluate the potential benefits and costs of a program to promote widespread adoption of phosphate fertilizers produced from indigenous phosphate supplies. We use the Malian situation (described in Henao and Baanante, 1999) to illustrate a general approach for conducting a benefit-cost analysis of a program to promote phosphate use.

5.2 *Identifying the objectives*

The Government of Mali (GOM) is interested in evaluating a program of Tilemsi phosphate rock (TPR) promotion because it believes that such a program could contribute to the realization of two government objectives:

A. Promotion of sustainable increases in private farm income and

B. Reduction in soil degradation and associated environmental damage

Secondary objectives include:

A. A reduction in the amount of foreign exchange spent on fertilizer imports (the reason for looking at TPR rather than manufactured triple superphosphate (TSP) or single superphosphate (SSP); and

B. Employment generation in phosphate production and marketing activities.

C. Positive effects on the government budget.

Multilateral and bilateral donors who might fund the phosphate promotion program support these objectives, but they also have a vested interest in the reduction of soil degradation if it contributes to a reduction in the production of greenhouse gases by increasing (or stopping the decline in) Mali's capacity to sequester carbon in trees, crops and soils.

The underlying assumption is that increased use of phosphates on Mali's phosphate-deficient soils would increase total plant biomass and crop yields, prevent land that is in continuous cultivation from becoming too degraded for cultivation, and slow down the rate at which woodlands and forests are being converted to crop land. Less degradation and destruction of forests would increase carbon sequestration and reduce greenhouse gases. To move forward with the analysis, one needs (1) to have technical coefficients to quantify the relationship between phosphate use and the anticipated physical outcomes, and (2) to be able to estimate the full costs of the phosphate program and value the full benefits of the phosphate use.

5.3 *Identifying the options to evaluate*

Henao and Baanante (1999) present individual results for five agroecological zones, two to three different crop rotations per zone, and eight alternative phosphate treatments per rotation (some using TPR and some using TSP). Rather than explicitly examining a "without" project scenario, Henao and Baanante (1999) calculated incremental ("with" minus "without") effects directly, such as decreased land degradation and decreased loss of carbon sequestration capacity as benefits of the phosphate program. Although treating the "without" situation implicitly in this way is an acceptable practice, we found that it led to some confusion in presentation and interpretation of the results, so the example here illustrates the alternative method of explicitly estimating benefits and costs for the non-project situation.

For simplicity's sake, we focus the present discussion on a single agroecological zone (Segou), a single crop rotation (millet / millet), and two project scenarios.

A. The "without" situation, which is characterized by a continuation of prevailing cropping patterns characterized by little if any use of organic fertilizers. We believe that this is represented in the IFDC study by the "phosphate control" scenario (Strategy 2, which includes a base level of N and K fertilization);

B. The TPR program, which is characterized by the promotion of the most profitable TPR treatment identified to date by agronomic research (120 kg / ha of TPR as a one-time basal application the first year followed by 15 kg / ha of TSP applied annually; this is Strategy 8 in the IFDC study).

5.4 *The numéraire*

The IFDC study (Henao and Baanante, 1999) estimated "private" benefits (net income to farmers in economic prices) and social benefits (private benefits plus net environmental benefits). The only apparent economic price adjustments were (a) valuation of fertilizer and crop output using import or export parity prices, i.e., prices based on world market prices adjusted for the cost of local transport and marketing, and the use of a lower discount rate for environmental benefits (3%) than for private benefits (5-20%). Another perspective reflected in the analysis was that of the global community (impact on carbon sequestration capacity). The secondary government objectives of employment generation and impacts on the government budget and foreign exchange balance were mentioned but not explicitly incorporated in the analysis.

5.5 *Enumeration and valuation of benefits and costs*

Costs. In looking at the project from the farmer's perspective the analyst will need to account for all the production costs for each scenario, taking care to estimate all the additional costs associated with the use of TPR or TSP (cost of the fertilizer itself; cost of complementary inputs required to get the anticipated response; transport and application costs; increases in crop harvesting, transport, and storage costs; etc.). The b-c calculation sin the IFDC study appear to have compared strategy 8 to strategy 2, implying that farmers in the "without" scenario were using 60-80 kg/ha of N and 15-25 kg/ha of K_2O (Henao and Baanante, 1999, p. 22). From the perspective of an agronomic analysis of P response, this is a logical approach but it has limitations for a benefit-cost analysis of a potential project because the typical millet farmer in the Segou Region does not currently use nitrogen or potassium fertilizers. We believe the cost of these complementary inputs should be taken into account if the true cost of P adoption at the farm level is to be reflected in the analysis.[5] (We will return to this issue later.)

In addition to farm-level costs, one needs to account for any costs incurred by the government (or the international community) for the promotion of the phosphate programs (extension, subsidies to stimulate phosphate demand and/or supply, interest on loans obtained to implement the program, etc.). The IFDC study did not explicitly consider program promotion costs. Other work on this subject (e.g., Howard, 1993; FAO, 2001) has shown that the success of a technology promotion program often depends on the provision of these types of services. We have include a notional estimate of these costs in our version of the analysis (tables 3 and 4), to reflect the view that farmers are unlikely to adopt phosphate fertilizers and the private sector is unlikely to produce TPR without government-funded promotion activities.

Finally, one needs to examine indirect costs that might be borne by society in general. For example, the IFDC considered the costs of pollution associated with increased phosphate use (eutrophication in water bodies and accumulation of heavy metals in soil). Both costs were deemed to be minimal in the Malian context and were not included in their b-c calculations.

Benefits. Quantifying the farm-level benefits requires good information on the physical crop response to the types of phosphate fertilizer applied, and the indirect effect of phosphate use on slowing land degradation. Quantifying broader environmental benefits such as carbon sequestration requires technical information on the likely effect of phosphate on the carbon-holding capacity of crop land, the likely impact of phosphate on land degradation and subsequent deforestation, and the carbon-holding capacity of a typical woodland or forest in the zone of interest. IFDC also considered as a benefit the potential reduction in industrial

[5] This is one of the reasons why we recommend a clear delineation of a "with" and "without" project situation. By looking at each situation separately the analyst is forced to account explicitly for some costs and benefits that are easily missed when the "without" situation is not examined separately.

pollution likely to be realized if TPR was used instead of TSP.[6] Valuation of the physical impacts will require output prices for the crops being produced, an estimate of the value of carbon that is sequestered in soils and forest cover, an estimate of changes in forest-generated incomes associated with deforestation, and valuation of the costs of cleaning up (or avoiding) the incremental pollution associated with different types of P production.

As noted earlier, the benefits associated with foreign exchange savings from reduced manufactured fertilizer imports would normally be handled by the use of shadow prices that incorporate the foreign exchange premium. The IFDC study does not appear to include any such foreign exchange premium, perhaps because it was felt that there was no significant overvaluation of the CFA franc following the 1994 devaluation. The benefits associated with employment creation, which would occur primarily in the Malian TPR production industry, also seem to have been omitted from the analysis. One way to incorporate such effects in the analysis would be simply to report the number of jobs, or the total wage bill, associated with project activity, in addition to reporting the calculated project NPV.

5.6 *Sustainability*

The analyst needs to take a long-term approach not only because the government is looking for a "sustainable" way of increasing crop yields and reducing soil degradation, but also because many of the benefits of improved soil quality and reduction in greenhouse gases are realized over a period of many years rather than during the year in which the phosphate fertilizer is applied. Ideally, the analyst should be able to estimate the flow of costs and benefits over a time horizon of 15-20 years, looking at both the financial (farm-level) and economic (societal) effects. To estimate societal costs and benefits adequately and to evaluate the economic sustainability of the program, the analyst needs to make projections of how rapidly farmers will adopt the phosphate packages and what this means for the streams of program promotion costs and anticipated benefits that will be derived from adoption. Because the IFDC analysis did not go beyond a calculation of benefits and costs for a single hectare of farmland, issues of scaling up the program were not taken into account.

5.7 *Gainers and losers*

The IFDC reports potential benefits per hectare for each of the 11 cropping systems analyzed, and includes a brief discussion of the distribution of net benefits, noting that they are positive for farmers (private benefits) and for the country as a whole (private plus environmental benefits). The report suggests (p. 38) that the regional or national community should pay about one-third of the cost of TPR investments, in rough proportion to the share of land conservation

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[6]This benefit accrues to countries where industrial phosphates are being produced, rather than to Mali, making it questionable whether the Malian government should take it into account when evaluating the different options. In explicitly comparing the "without" situation with the TPR situation, one could argue that there will be increased pollution in Mali associated with expansion of TPR production (particularly if partially acidulated phosphate rock is used) and that this should be factored in as a cost of the TPR program.

and environmental protection benefits which they receive as a result of farmers' use of phosphate.

5.8 *Uncertainty*

In the case of phosphate promotion, uncertainty exists about the physical coefficients being used to estimate some of the costs and benefits. There is uncertainty about the crop response to phosphates because this varies by soil type and weather conditions. Modeling used by IFDC to estimate fertilizer response did take into account variability in rainfall but not risks of crop loss due to pests or disease. Uncertainty is even greater for estimates of carbon sequestration and the rate at which crop land becomes totally degraded in the "without" project scenario because the tools available for measuring these factors are relatively new (see, for example, Kuyvenhoven, Becht, and Ruben, 1995; Brown and Pearce, 1994; Throsby, 1995). Dealing with future trends for prices used in valuing costs and benefits is another area of uncertainty as is the choice of a discount rate. The approach used by IFDC was to assume that price relationships prevailing in the year of analysis (1995) would remain approximately the same over time so no price projections were developed. The only sensitivity analysis taken into account was on the private discount rate which was set at four different levels (5, 10, 15, and 20%); the social discount rate (applied to the environmental benefits) was constant at 3%.[7]

5.9 *Data requirements*

The discussion in the previous paragraphs (especially 5.5) has alluded to the broad categories of data required for the benefit-cost analysis of the two scenarios: without phosphate fertilizer and with application of TPR. Tables 2-4 illustrate the information used in the Mali phosphate study by Henao and Baanante. Table 2 is an attempted replication of the analysis by Henao and Baanante (1999). Tables 3 and 4 represent another way of structuring the analysis, based on a combination of real data drawn from Henao and Baanante (1999) and supplementary sources which we consulted. The figures in italics are rough estimates of parameters upon which an analyst would need to improve.

5.10 *Discussion of the example presented*

IFDC approach. In table 2, strategy 8 (120 kg basal TPR plus 15 kg annual TSP-3) is compared to Strategy 2 (no phosphate), for one hectare of continuous millet cultivation in Segou. The same level of N and K fertilization is incorporated in each strategy (which we took to be 70 kg of urea and 20 kg of potassium sulfate per hectare per year, i.e., the midpoints of the ranges

[7]While the approach is controversial, it is not uncommon for b-c analysts to advocate use of lower discount rates when evaluating environmental benefits. Reasons for doing so include the view that this is necessary to incorporate the sustainability objective (since at normal discount rates benefits received more than 20-25 years in the future have negligible present value), that discounting constitutes a bias against the interests of future generations, and that on theoretical grounds the "social" discount rate is lower than the "private" discount rate. See Ch. 8 of Hanley and Spash (1993) for a good discussion of these issues.

indicated in Henao and Baanante, p. 22). Incremental yields are the difference between yields calculated for Strategy 8 and those for Strategy 2. Net benefits are broken down into private (farm-level economic), environmental, and social (the sum of private and environmental). The NPV figures given in table 2, calculated for one six-year yield simulation, show higher private benefits (478.3 versus 313.3) than those in Henao and Baanante. Because their report did not include budgets showing the derivation of private benefits, we are unable to explain this difference.[8]

Crawford/Kelly approach. Tables 3 and 4 explicitly portray the without-phosphate and with-phosphate scenarios, and the underlying assumptions about levels and changes in aggregate areas of cultivated, degraded, and forest land. For each scenario, the line items are divided into four groups: a land use scenario (rows 1-4) that specifies assumptions about how much land is cultivated, degraded, and left in woodlands/forests, a list of benefits, a list of costs, and a calculated net benefit. Rows 26-27 in table 3, and rows 26-28 in table 4, show the environmental costs. The columns contain costs and benefits for each year of the analysis and permit discounting over time.

Quantifying and Valuing Environmental Factors. The most difficult conceptual part of this analysis is accounting for the environmental costs and benefits. Henao and Baanante hypothesize that several things will happen if a phosphate program is not implemented: (1) P_2O_5 balances in the soil will decline at a rate estimated to be 1.8 kg/ha/yr due to nutrient mining and another 2.7 kg/ha/yr due to erosion, (2) after ten years of continuous cultivation without adding nutrients and protecting against erosion, the soil becomes so degraded that farmers will abandon it (a loss of productive capacity estimated at $120/ha, or $12/ha/year if averaged across the 10 years), (3) the amount of carbon sequestered in the soils will decline due to erosion (0.72 tons of carbon/ha/year valued at US $7.20), (4) farmers will replace the abandoned field by clearing a hectare of woodland or forest, with the subsequent loss of carbon sequestered by the forest valued at US $57.40 for each hectare converted to crop land.[9] Care must be taken to avoid double counting when considering all these consequences. For example, the loss of soil P is a cause of the soil degradation that renders land unfit for cultivation, hence either the soil P changes or the loss of productive land can be taken into account, but not both simultaneously.

One option would be to keep track of changes in plant-available P_2O_5 balances, valuing increases or decreases in balances at the prevailing cost of P_2O_5 fertilizers—an approach often taken by agronomists or soil scientists). An economist would prefer to evaluate the changes in P balances by reporting the likely changes in yields associated with increased or decreased levels of soil P (changes in production are easier to value accurately than changes in stocks). The problem with this method is that the scientific literature is not clear about the extent to

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[8]We came much closer in our effort to replicate the Henao and Baanante estimate of the NPV of environmental benefits (354 versus 345.2 for the full 18-year period).

[9]There is no clear explanation in the text of how this value is derived, but it is a one-time loss (i.e., not taken into account on an annual basis).

which different P balances affect yields in the current or in future years. Henao and Baanante used an intermediate approach—rather than trying to value changes in soil P, they focused on their estimates of crop land degradation. Having estimated that P losses through nutrient depletion and soil erosion would lead to total degradation of crop land after 10 years of use in continuous cultivation, the authors argued that a benefit of the phosphate project would be the preservation of the productive capacity of crop land in perpetuity—the value would be based on the value of average annual production per hectare. Looking at this situation from the "without" project scenario, the analyst would consider the loss of one hectare of crop land every ten years as a cost, valued at the foregone productive capacity of that land, e.g., an average of $12 / year or a loss every ten years of $120.

Summary comparison of the IFDC (Table 2) and Crawford / Kelly approaches (Tables 3, 4). The IFDC approach includes as a benefit the avoided pollution cost of wet-process manufacturing of P fertilizer. This is excluded from the Crawford / Kelly approach on the grounds that this benefit accrues in the manufacturing countries, and is not relevant to Mali. The Crawford / Kelly approach includes several items or features not found in the IFDC study:

a. Explicit representation of the "with-project" and "without-project" scenarios. For example, while the IFDC study shows the reduction in land degradation due to P fertilizer use as a direct benefit, the Crawford / Kelly approach shows this indirectly as the difference between zero land degradation with the project and increasing land degradation without the project.

b. An explicit breakdown of assumed changes in the amount of forest land, cultivated land, and degraded land.

c. The impact on costs and benefits of clearing forest land to replace land that has degraded to the point of being uncultivable. These include changes in aggregate income from forest land, wood sales after clearing forest land, and the labor cost of clearing forest land. (The carbon sequestration value of avoiding forest clearing is included in both approaches.)

d. The costs of project implementation, including promotion of TPR production and extension campaigns to encourage farmer use of TPR.

e. The costs of pollution associated with local TPR manufacturing.

Table 2. IFDC Phosphate Study: Segou Example (Strategy 8 vs. Strategy 2)

		Year					
		1	2	3	4	5	6
1	**Benefits:**						
2	Incremental grain yield (kg/ha)	549	600	736	753	806	812
3	Incremental stover yield (kg/ha)	1,056	1,115	1,282	1,334	1,438	1,437
4	Incremental grain value ($/ha)	55.45	60.60	74.34	76.05	81.41	82.01
5	Incremental stover value ($/ha)	38.02	40.14	46.15	48.02	51.77	51.73
6	**Total crop value ($/ha) (1)**	**93.46**	**100.74**	**120.49**	**124.08**	**133.17**	**133.74**
7							
8	Reduction in land degradation ($/ha) a/	12	12	12	12	12	12
9	Carbon sequestration value ($/ha) b/	7.2	7.2	7.2	7.2	7.2	7.2
10	Prevention of deforestation value ($/ha) c/	5.74	5.74	5.74	5.74	5.74	5.74
11	Prevention of pollution value ($/ha) d/	0.8	0.8	0.8	0.8	0.8	0.8
12	**Total environmental benefits ($/ha) (2)**	**25.74**	**25.74**	**25.74**	**25.74**	**25.74**	**25.74**
13	**TOTAL BENEFIT ($/ha) (3)=(1)+(2)**	**119.20**	**126.48**	**146.23**	**149.82**	**158.91**	**159.48**
14							
15	**Costs:**						
16	TPR cost ($/ha) e/	70.08					
17	TSP cost ($/ha) f/	8.98	8.98	8.98	8.98	8.98	8.98
18	Incremental N and K fertilizer cost ($/ha) g/	0	0	0	0	0	0
19	Fertilizer application costs ($/ha) h/						
20	**TOTAL COST ($/ha) (4)**	**79.065**	**8.985**	**8.985**	**8.985**	**8.985**	**8.985**
21							
22	**Private Net Benefit (5 = 1 - 4)**	**14.4**	**91.755**	**111.503**	**115.092**	**124.189**	**124.759**
23	**Social Net Benefit (6 = 3 - 4)**	**40.14**	**117.495**	**137.243**	**140.832**	**149.929**	**150.499**
24							
25	**NPV Private @ 5% (7)**	**478.3**					
26	**NPV Environmental Benefits @ 3% (8)**	**139.4**					
27	**NPV Social Net Benefits (9 = 7 + 8)**	**617.8**					

Source: Adapted from Henao and Baanante, 1999.

a/ Value of farm income losses due to soil degradation, estimated using region-specific farm budgets.

b/ Estimated carbon losses due to soil erosion, valued at $10 per ton of C.

c/ Value of carbon losses caused by deforestation, averaged across ten years (time estimated for complete soil degradation).

d/ Cost of point pollution due to phosphogypsum produced in manufacture of wet-process P fertilizers.

e/ 120 kg/ha P_2O_5 content at $0.584/kg.

f/ 15 kg/ha P_2O_5 content at $0.599/kg.

g/ Same level of N and K fertilizer in both Strategies 8 and 2 (70 kg/ha urea + 20 kg/ha potassium sulfate).

h/ Apparently included in the farm-level cost of fertilizer (Henao and Baanante, p. 32).

Table 3. "Without"Project Situation for millet/millet rotation in Segou Region (Strategy 1)

		Year					
		1	2	3	4	5	6
	Land use assumptions						
1	Forest/Woodland (ha)	*230,000*	*188,000*	*146,000*	*104,000*	*62,000*	*20,000*
2	Loss of forest/woodland (ha)		*42,000*	*42,000*	*42,000*	*42,000*	*42,000*
3	Cultivated area (ha)	*420,000*	*420,000*	*420,000*	*420,000*	*420,000*	*420,000*
4	Degraded crop land (ha) a/	*120,000*	*162,000*	*204,000*	*246,000*	*288,000*	*330,000*
5	**Benefits**						
6	Aggregate value of crop production (U.S. $'000)	28,580	24,977	13,501	16,251	17,698	13,892
7	Area cultivated ('000 ha)	420	420	420	420	420	420
8	Grain yield (tons/ha) b/	0.44	0.381	0.206	0.248	0.27	0.212
9	1995 Import parity price of grain ($/ton)	101	101	101	101	101	101
10	Stover yield (tons/ha) b/	0.67	0.583	0.315	0.379	0.413	0.324
11	1995 Import parity price of stover ($/ton)	36	36	36	36	36	36
12	Aggregate forest income ($/ha* ha, in $'000)	460	387	310	227	140	46
13	Forest area ('000)	230	188	146	104	62	20
14	Value ($/ha) c/	*2.00*	*2.06*	*2.12*	*2.19*	*2.25*	*2.32*
15	Wood sales after clearing forest land ($'000)	*0*	*210.0*	*273.0*	*354.9*	*461.4*	*599.8*
16	**Total Benefits (million US $)**	**29.04**	**25.57**	**14.08**	**16.83**	**18.30**	**14.54**
17	**Costs**						
18	Aggregate fertilizer cost (U.S. $'000)	0.00	0.00	0.00	0.00	0.00	0.00
19	Area treated ('000 ha)	0	0	0	0	0	0
20	Urea cost ($/ha)	0	0	0	0	0	0
21	Potassium sulfate cost ($/ha)	0	0	0	0	0	0
22	TPR cost ($/ha)	0	0	0	0	0	0
23	TSP cost ($/ha)	0	0	0	0	0	0
24	Labor cost of clearing new land ($25/ha) $'000		*1050*	*1050*	*1050*	*1050*	*1050*
25	Loss of carbon sequestration capacity $'000						
26	Soil losses ($7.20/ha/year*area cultivated)	3,024	3,024	3,024	3,024	3,024	3,024
27	Forest losses ($57.40 /ha lost) d/		2,411	2,411	2,411	2,411	2,411
28	**Total Costs (million US $)**	**3.02**	**6.48**	**6.48**	**6.48**	**6.48**	**6.48**
29	**Net Benefits (million US $)**	**26.02**	**19.09**	**7.60**	**10.35**	**11.81**	**8.05**
30	**Net Present Value (10%), million US $**	**64.09**					

Figures in italics are rough estimates or notional numbers.

a/ If each hectare is degraded after ten years of cultivation without fertilizers, this is equal to 10% of cultivated area moving to degraded each year and being replaced with equivalent in forest.

b/ Same as used in IFDC study.

c/ As forest becomes scarce, value of forest products and forest income increases at average rate of 3%/year.

d/ Valuing C at $10/ton, and assuming 1 ha lost per 10 years.

Table 4. TPR Project Situation (Strategy 8 vs 1)

		Year					
		1	2	3	4	5	6
	Land use assumptions						
1	Forest/Woodland (ha)	*230,000*	*230,000*	*230,000*	*230,000*	*230,000*	*230,000*
2	Loss of forest/woodland (ha)		*0*	*0*	*0*	*0*	*0*
3	Cultivated area (ha)	*420,000*	*420,000*	*420,000*	*420,000*	*420,000*	*420,000*
4	Degraded crop land (ha)	*120,000*	*120,000*	*120,000*	*120,000*	*120,000*	*120,000*
5	**Benefits**						
6	Aggregate value of crop production (U.S. $'000)	92,997	84,198	64,442	76,023	85,706	81,198
7	Area cultivated ('000 ha)	420	420	420	420	420	420
8	Grain yield (tons/ha) a/	1.365	1.236	0.946	1.116	1.258	1.192
9	1995 Import parity price ($/ton)	101	101	101	101	101	101
10	Stover yield (tons/ha) a/	2.321	2.101	1.608	1.897	2.139	2.026
11	1995 Import parity price of stover ($/ton)	36	36	36	36	36	36
12	Aggregate forest income ($/ha* ha, in $'000)	*460*	*460*	*460*	*460*	*460*	*460*
13	Forest area ('000)	*230*	*230*	*230*	*230*	*230*	*230*
14	Value ($/ha) b/	*2*	*2*	*2*	*2*	*2*	*2*
15	Wood sales after clearing forest ($'000)	*0*	*0*	*0*	*0*	*0*	*0*
16	**Total Benefits (million US $)**	**93.46**	**84.66**	**64.90**	**76.48**	**86.17**	**81.66**
17	**Costs**						
18	Aggregate fertilizer cost (U.S. $'000)	41,985	12,552	12,552	12,552	12,552	12,552
19	Area treated ('000 ha) c/	420	420	420	420	420	420
20	Urea cost ($/ha) d/	18.90	18.90	18.90	18.90	18.90	18.90
21	Potassium sulfate cost ($/ha) e/	2.00	2.00	2.00	2.00	2.00	2.00
22	TPR cost ($/ha) f/	70.08					
23	TSP cost ($/ha) g/	8.98	8.98	8.98	8.98	8.98	8.98
24	Labor cost of clearing new land ($25/ha)						
25	Loss of carbon sequestration capacity						
26	Soil losses ($7.20/ha/year*aggregate ha cultivated) h/						
27	Forest losses ($57.40 /ha lost)						
28	Pollution from TPR production ($.10/kg) $'000	*5,040*	*5,040*	*5,040*	*5,040*	*5,040*	*5,040*
29	Project promotion costs (extension, etc.) $'000						
30	Extension ($2/ha yr 1; $1 yr 2, $.5 yr 3)	*840*	*420*	*210*			
31	Promotion of TPR manufacturing	*50,000*	*250*	*250*			
32	**Total Costs (million US $)**	**97.87**	**18.26**	**18.05**	**17.59**	**17.59**	**17.59**
33	**Net Benefits (million US$)**	**-4.41**	**66.40**	**46.85**	**58.89**	**68.57**	**64.07**
34	**Incremental NB (TPR - Without Project)**	**-30.42**	**47.31**	**39.25**	**48.54**	**56.76**	**56.01**
35	**Net Present Value of TPR (10%), million US $**	**205.03**					
36	**NPV of Incremental NB, million US $**	**140.95**					

Figures in italics are rough estimates or notional numbers.

a/ Assuming immediate adoption of TPR by all farmers on all fields.

b/ As forest becomes scarce, value of forest products and forest income increases at average rate of 3%/year.

c/ Assumes all crop land is treated.

d/ 70 kg/ha times price of $0.27/kg.

e/ 20 kg/ha times price of $0.10/kg.

f/ 120 kg/ha once in six years, times price of $0.584/kg.

g/ 15 kg/ha annually, times price of $0.599/kg.

h/ Valuing C at $10/ton.

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