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Consideration of Natural Disasters in the Economic Analysis of Agricultural Development Projects

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Abstract: Nearly 90 percent of the world's natural disasters occur in LDCs. Agricultural sectors are particularly prone to economic damage from natural disaster, yet, economic analyses of agricultural development projects seldom recognize the potential impacts of natural disasters on project net benefits. Several methods are available for incorporating natural disaster information into benefit-cost analysis. Using data from a development project in St. Lucia, a stochastic simulation approach is applied to assess the feasibility of the project with and without a disaster mitigation practice. The mitigation practice is the use of nematocides to reduce wind damage to newly established banana plantings. Mitigation is found to lower the project's expected internal rate of return and to lower the riskiness of the project. This type of information could be useful to project planners for evaluating disaster mitigation measures and for selecting among competing projects.

Introduction

Approximately 90 percent of the world's natural disasters occur in LDCs. When the natural disasters strike, they often have short- and long-term effects on economic activity. Agriculture in LDCs is particularly prone to economic damage from natural disasters for two reasons. First, agriculture is frequently a major, if not the dominant, economic activity. Second, agriculture tends to have less institutional and infrastructural protection from natural disasters than is the case in developed countries. Yet, the planning process for agricultural development seldom considers natural disaster information in a systematic manner.

The purpose of this paper is to review methods to incorporate natural disaster information into development plans and to illustrate the use of one of the approaches in an analysis of a development project on the Caribbean island of St. Lucia.

Natural Disasters and Economic Development

Because agriculture is the basic sector in many of the countries most prone to natural disasters, the resulting disruptions can have far-reaching economic consequences. Large shortfalls in agricultural production can have ripple effects throughout the economy, not only reducing food supplies but affecting employment and spending in other sectors of the economy as well.

Let us consider some examples of the economic damages storms have inflicted on agriculture. When hurricanes David and Frederick struck the Dominican Republic in 1979, they caused an estimated \$342 million of damage to the agricultural sector. The hurricanes destroyed the entire banana crop (UN, 1980). In a country where agriculture provides employment for 40 percent of the labour force and accounts for 37 percent of the GDP, the storms had a major affect on the economy (USAID, 1982).

In 1984, the worst floods in Colombia in a decade caused an estimated \$400 million of damage to crops and livestock, and floods in Ecuador in 1982 and 1983 reduced the value of the banana crop by \$4.3 million (UN, 1983). These are only a few examples of the direct effects of natural disasters on agricultural sectors.

In addition to these immediate economic impacts, natural disasters can have long-term impacts on the development process. Earthquakes, floods, and other natural disasters destroy a country's productive assets, including roads, bridges, buildings, port facilities, and agricultural enterprises. Given that natural disasters divert a country's savings into recovery uses rather than the creation of new productive assets, they can slow development. This suggests that the destruction of productive capital by natural disasters can help explain some of the differences in economic well-being around the world (Deaton, undated).

Greater attention should be paid to the potential effects of natural disasters on development projects. One contribution that economists could make would be to conduct benefit-cost analyses of disaster mitigation measures to determine if financial resources could be better spent preventing damage rather than recovering from it.

Natural Disasters and Project Planning

A development project represents an investment of capital to create assets capable of producing a future stream of net benefits. Careful project planning is considered a critical determinant of the success of a project. A variety of ways exist to characterize the project planning cycle. The planning process generally includes these three phases: identification, prefeasibility analysis, and feasibility analysis. The identification phase is finding potential projects in the country of interest. The prefeasibility phase involves a rough determination of project benefits and costs. Some projects can be eliminated from further consideration based on the prefeasibility analysis. The feasibility analysis phase considers the technical and economic viability of a project. Refined estimates are made of evaluation criteria such as internal rates of return or benefit-cost ratios.

Although not widely done, natural disaster information can be used at each planning phase. At the identification phase, risk maps and disaster return frequencies can be consulted to eliminate high-risk project locations. If the location cannot be easily shifted, disaster mitigation measures can be included as part of the project design. In the prefeasibility analysis, probabilities of natural disasters can be estimated and used to adjust project costs and benefits. In the feasibility phase, more precise information on the probabilities and consequences of disasters can be collected and used in a formal benefit-cost analysis.

To incorporate natural disaster information into an agricultural project feasibility analysis, one should ideally have information on the probability of the disaster, intensity of the event, and likely damage to agriculture. To obtain this type of information may not be easy, particularly in LDCs, although the probability or risk of the event often can be determined from weather data. The intensity can also be determined this way. Potential damage is more difficult to assess but can be roughly estimated with the help of agronomists and horticulturalists.

Including Natural Disaster Information in Benefit-Cost Analysis

Benefit-cost analysis is a method used by economists to determine the efficiency of public-sector investments. It can be a part of both the prefeasibility and feasibility analysis phases of project planning. The usual approach consists of enumerating all benefits and costs, evaluating all benefits and costs in monetary terms, and discounting future net benefits.

The problem with this typical approach to benefit-cost analysis in areas affected by natural disasters is that it fails to account for the fact that the future benefits of a project are highly uncertain. For example, the major benefits of a project to provide irrigation water to farmers will be higher yields. However, if these yields were severely curtailed in those years when a tropical storm occurs, the usual benefit-cost study would fail to reflect this.

Several methods exist for incorporating uncertainty into benefit-cost analysis (for a review of such methods, see Kramer and Florey, 1987). Those that demand less data can be conducted with limited information on the effects of natural disasters on project net benefits. More sophisticated approaches require probability distributions of net benefits.

The limited-information approaches include sensitivity analysis, discount rate adjustments, cutoff periods, and minimax and maximin strategies. All these approaches attempt to adjust project net benefits to reflect uncertainty. For example, analysts examining

a project for a flood-prone area might use a high discount rate to reflect that the future stream of benefits may be disrupted by floods. These limited-information approaches recognize that natural disasters can influence a project's feasibility, but they are crude in their ability to convey useful information to decision makers.

If information is available to allow the analyst to estimate the probability distribution of the project's net present value (or other economic feasibility measure), one can use the probability distribution to conduct an expected-value analysis, mean-variance analysis, or safety-first analysis (Reutlinger, 1970). The expected-value analysis uses the probability distribution to compute a mean return measure. This approach is inadequate because it ignores useful information about higher moments. A safety-first approach considers the probability of a project earning a rate greater than some critical level. While useful in some contexts, the definition of the critical level is arbitrary. In this study, a mean-variance approach is taken to generate information on the mean and variability of project returns.

Case Study: Agricultural Development Project in St. Lucia

To demonstrate a method for incorporating natural disaster information into agricultural project analysis, a case study was developed. The case study chosen was based on an agricultural development project on the Dennery Estate in St. Lucia. The case study focused on a major component of the Dennery project—increasing banana production.

Bananas are the major crop in St. Lucia, planted on 71 percent of the arable land. Bananas are the largest export earner, but export volume is highly variable. During 1970-84, export volume fluctuated widely between 29,000 and 64,000 tons (World Bank, 1985). One of the reasons for the fluctuations is production shortfalls caused by natural disasters. Banana crops are susceptible to damage from drought, high winds, and hurricanes (Simmonds, 1987; and Hammerton, George, and Pilgrim, 1979). The drought problem is the subject of intensive research and a solution is being sought through irrigation development. Damage caused by high winds and hurricanes cannot be mitigated as easily. Crop damage results from defoliation and stripping of fruit, breaking and bending of stems, uprooting, flooding, and soil erosion. The uprooting problem can be lessened with improved control of nematodes.

The Dennery Estate in the central part of the island was purchased by the government in 1978 to avert an impending bankruptcy. In 1984, the Organization of American States (OAS) began a project to assist the government of St. Lucia to rehabilitate the Dennery Estate, a major employer in an area with high unemployment. Approximately 300 acres were targeted for new plantings of banana trees.

The case study project used to illustrate the incorporation of natural disaster information was development of banana production on 300 acres, half of which will be irrigated. Other activities of the larger project, such as land reform and soil conservation, were not considered in this analysis. Actual project data (OAS, 1985) were used wherever possible, although some assumptions and simplifications were necessary due to incomplete data.

Existing roads were considered adequate to service the additional farm production, so the only new infrastructure needed was an office, temporary storage facilities, a toilet, a workshop, and a garage. Other initial investment costs were the purchase of a jeep, the construction of an irrigation system, and land clearing. Cost data were obtained from the OAS project proposal. These investment costs totalled EC\$1,359,450 (East Caribbean dollars).² The cost data are summarized in Table 1.

Operating costs for the project include transport, security, and debt-service activities. Operating costs totalled EC\$519,275 for the first year and increased slightly in later years due to increased transport costs. Costs for producing the bananas were EC\$532,200 in the first year and dropped to EC\$476,700 in subsequent years.

The major benefit associated with the project is increased banana production: 1,074 tons in the first year and 1,434 tons in subsequent years. Because of the high unemployment in the area, wages paid to labour were considered a project benefit. In

Table 1-Annual Benefits and Costs for an Agricultural Development Project in St. Lucia

	First Year	Subsequent Years
<i>East Caribbean dollars</i>		
Benefits:		
Income from banana production	397,595	530,866
Direct employment	621,736	572,896
Off-farm employment	269,016	359,188
Road maintenance	20,000	20,000
Total benefits	1,308,346	1,482,951
Costs:		
Initial capital costs	1,359,450	--
Production costs	532,200	476,700
Other operating costs	519,275	519,914
Total costs	2,410,925	996,614

Source: OAS (1985).

addition to the labour benefits from direct employment, additional labour benefits of EC\$259 per ton were associated with processing and handling of the bananas. The project benefits, shown in Table 1, totalled EC\$1,308,346 in the first year and EC\$1,482,951 in subsequent years.³

The data on project benefits and costs in Table 1 are sufficient for conducting a standard benefit-cost analysis. However, this study also required information on the economic impacts of natural disasters on the project. Table 2 shows data on return frequencies for four types of natural events affecting banana production. Estimates of yield declines resulting from the events are also shown. Hurricanes can cause the greatest damage, reducing yields by 90 percent, but have a rather low return frequency of 6 percent. Both droughts and tropical storms have return frequencies of about 14 percent, but the yield damage from tropical storms is much greater. High winds occur rather frequently but have a moderate effect on yields.

Table 2-Disaster Return Frequencies and Estimated Yield Effects

	Return Frequency	Yield Decrease
- - - Percent - - -		
Hurricane	5.95	90
Drought	14.28	15
Tropical storm	14.81	60
Moderate winds (13-24 mph)	34.20	20

Sources: O'Keefe and Shakow (1975); O'Keefe and Westgate (1974); and NOAA (1941-49).

Initially, the effects of these weather events were captured indirectly in the analysis by using historical yield probabilities. Banana yield data for the Dennerly Estate were obtained for 1970-84 (OAS, 1985). The yields were highly variable, ranging between 2.77 and 8.15 tons per acre. These data were used to estimate a probability distribution for yields from which random draws were generated.

The randomly drawn yields were then used to adjust the benefits and costs, and an internal rate of return was calculated for each state of nature. In effect, this generated a probability distribution of net benefits. From this, an average internal rate was calculated. In addition, a coefficient of variation was calculated as a measure of the variability in project returns. The random-number generation and benefit-cost calculations were carried out with a stochastic simulation program developed by the authors.

Next, the effects of a disaster mitigation practice were analyzed. A mitigation practice recommended by experts on the island is the use of nematicides. Treatment with nematicides strengthens the roots and reduces the probability of wind storms uprooting the

banana plants. However, this practice is ineffective in protecting against the high wind speeds associated with hurricanes. Based on information in Simmonds (1966) and the OAS Dennery project proposal, the use of nematicides was estimated to increase establishment costs by EC\$74 per acre and production costs by \$EC270 per acre. The major benefit would be higher yields in those years with wind storms.

To estimate the yield effect of the mitigation practice, the historical yield data were reexamined. The three lowest yields occurred in 1976, 1978, and 1979. These low yield levels were assumed to be due to the effects of high winds, since they occurred in years when neither a hurricane nor a drought affected the island. The yields in those three years were 22, 18, and 23 percent lower than the historical mean. The average yield decline, 21 percent, is close to the 20-percent estimate of wind damage reported in Table 2. Assuming that the mitigation measure would prevent damage from the wind storms, the three lowest yields were dropped and replaced by the average for the remaining years. A new probability distribution was then estimated and used to calculate the probability distribution of rates of returns with the mitigation measure. The decision to replace the three lowest years was admittedly somewhat arbitrary, but should illustrate the mitigation benefits.

Without mitigation, the mean rate of return to the agricultural development project is 29.5 percent, a rather high return. The coefficient of variation is 69 percent. Adding the mitigation practice to the project lowers the expected rate of return to 27.6 percent. However, this reduction in expected return has bought a reduction in risk associated with the project. The coefficient of variation declines to 62 percent, indicating that, as expected, less risk is incurred with the mitigation practice implemented. Depending on their degree of risk aversion, project planners or policy makers might be willing to trade off the reduction in expected return for a lower variation in returns.

Conclusions

Development organizations use feasibility studies to determine the economic potential of agricultural development projects. Little attention is paid to the effects that natural disasters may have on a project's economic viability. Yet, agricultural projects are often affected by natural disasters, particularly in tropical areas.

Several methods are available for considering information on natural disasters when carrying out project feasibility analysis. One such method was illustrated with an application to an agricultural development project in St. Lucia. Using a simulation model, internal rates of return were computed for different states of nature. Altering the original project to include a disaster mitigation measure (treatment of banana trees with nematicides) lowered the expected internal rate of return to the project but also made project returns less risky. If feasibility studies regularly included this type of analysis, project planners could compare the relative riskiness of alternative projects. Furthermore, careful analysis of the risk effects of mitigation measures could help decision makers determine whether or not to include disaster mitigation in their development projects.

Notes

¹School of Forestry and Environmental Studies, Duke University; and Foreign Agricultural Service, US Department of Agriculture; respectively.

²At the time of the study, US\$1 was equivalent to EC\$2.70.

³For more information on the project benefits, see Florey (1986).

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DISCUSSION OPENING—*Des Doran* (Agriculture Development Branch, Agriculture Canada)

I agree with the authors that more attention should be paid to the potential effects of natural disasters. I need not cite a long list of such disasters. To quote the well-known Jamaican proverb about hurricanes:

*June, too soon
July, stand by
August, come it must
September, remember
October, all over*

All over, that is, except the reconstruction; hence, the need for disaster-mitigating activities.

The authors are right to direct attention to the need for more work in the area of evaluating the relative merits of expenditures for measures to prevent damages from disasters versus expenditures for measures to recover from them. Unfortunately,

governments of developing countries frequently pose the task to agricultural planning teams in terms of their perception of directly productive activities. Similarly, agricultural economists are frequently called on to evaluate project impacts of technical designs that failed to consider more feasible alternatives.

Nevertheless, current project formulation and evaluation practices are used to deal with disaster-type information. Where an agricultural development project is the work of a team of specialists, including agronomists, soil scientists, animal husbandry specialists, irrigation engineers, etc., then a great deal of "environmental" data will be incorporated into a project. For example, irrigation engineers plan irrigation works with the possible disastrous effects of the 100-year flood clearly in mind. I recall how delighted the hydrologists and hydrogeologists were on one project in Africa to find a store house of climatic data for 60 or more years in the country. Resettlement villages were sited with a host of possible disaster factors in mind. My point here is that current practices include attention to national disaster factors.

The provision of measures of the degree of risk associated with a proposed agricultural development project, by the economic analyst, will affect the decision making of the government or institution that proposes the project and of the agency (national or international) that will provide financing for the project. We shall want to know something about the risk preference frontiers.

A possible outcome of the proposed change in the way projects are evaluated could thus be that projects that have a "lower" rate of return and a "higher" degree of risk will be proposed and funded. What kinds of projects display these characteristics of low expected rates of return and high degrees of risk? Some technology innovation projects probably fall into this category, and further examining the possible effects on a country's agricultural development of selecting more of such projects at the expense of other projects would be useful.

GENERAL DISCUSSION—*Bill R. Miller, Rapporteur* (Department of Agricultural Economics, University of Georgia)

A comment was made that the methodology seemed more appropriate for low risk, high payoff activities. Would it apply to situations where survival might force a high-risk decision? Kramer responded that the methodology presented is appropriate for economic development planning and not necessarily for decision making at the consumer or producer level.

In his response to the discussion opener, Kramer said that disaster prevention was not a popular concept among development planners as it does not focus on positive effects. The positive pay-offs from a project, such as a school, are much more likely to be the subject of research. However, if the implicit assumption made by engineers with respect to events such as a 100-year storm could be made explicit, then they might be quantified and contribute to economic analysis.

Participants in the discussion included J. McKinsey.