An illustration: Disaster mitigation for an agricultural project in St. Lucia

In this section, a case study of an agricultural development project on the Caribbean island of St. Lucia is introduced to illustrate the use of natural disaster information in benefit-cost analysis (Kramer and Grieco 1989). The project was designed to promote agricultural and natural resource development with an emphasis on crop production. The case study focuses on banana production on the Dennery Estate.

Bananas comprise the major agricultural activity in St. Lucia and were planted on 71 percent (10,000 acres) of the arable land at the time of the study. Banana production fluctuates widely; during 1970–84, the volume of exports ranged from 29,000 to 64,000 tons. The high variability of exports was due in part to production shortfalls arising from drought, high winds, and hurricanes (Hammerton, Calixte, and Pilgrim 1979). Efforts to address drought problems have relied on irrigation development. Damage from hurricanes and high winds is less amenable to mitigation. Crop damage can result from the defoliation action of rain, as well as leaching, erosion, uprooting, and flooding that result from the prolonged heavy rains that accompany hurricanes. The uprooting problem can be diminished by controlling nematodes, which weaken root systems.

The Dennery Estate was purchased by the government in 1978 to avert bankruptcy and assure stable employment in the area. In 1984, the Organization of American States (OAS) initiated a project to aid the government in rehabilitating the estate to increase agricultural income and employment. Because banana production was the major income producer for the estate, the project targeted 300 acres for new plantings of banana trees. The case study used OAS project data whenever possible, but no information was available on natural disasters. Additional data were introduced to conduct the risk analysis.

Existing roads were considered adequate to handle the additional farm production, so the new infrastructure was limited to a few buildings. Other initial investments included the purchase of a vehicle, the installation of irrigation equipment, and land clearing. The investment costs, obtained from the OAS project proposal, totaled EC$1,359,450 (East Caribbean dollars; see table 4-1). Operating costs for the project, which include transportation expenses and security, totaled EC$519,275 for the first year and increased slightly in later years due to higher transportation costs associated with rising yields. The production costs, including planting, weeding, fertilizing, and pesticide application, were EC$532,200 in the first year and dropped to EC$476,700 in later years.[5] These costs are also summarized in table 4-1.

The primary benefit of the project was the increased production of bananas. In the first year, 1,074 additional tons resulted from the project; in subsequent years, the projected mean yield was 1,434 tons a year. Based on growers' price, these annual production figures represented EC$397,595 and EC$530,866, respectively. Because of high unemployment in the area, wages paid to laborers were considered an additional project benefit.[6] Total project benefits, shown in table 4-1, were estimated to be EC$1,308,347 in the first year and EC$1,482,951 in subsequent years.

A conventional benefit-cost analysis could be conducted based on the data in table 4-1, but such an analysis would clearly be inadequate for consideration of

Table 4-1: Annual Benefits and Costs for an Agricultural Development Project in St. Lucia
(in East Caribbean dollars)

Benefits and costs	*First year*	*Each subsequent year*
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	1,308,347	1,482,951
Costs		
Initial capital costs	1,359,450	n.a.
Production costs	532,200	476,700
Other operating costs	519,275	519,914
Total costs	2,410,925	996,614

n.a. Not applicable.

Table 4-2: Disaster Return Frequencies and Estimated Effects on Yield
(percentages)

Type of disaster	*Return frequency*	*Decrease in yield*
Hurricane	5.95	90
Drought	14.20	15
Tropical storm	14.81	60
Moderate winds (13 to 24 miles per hour)	34.20	20

Source: Florey 1986.

the impacts of natural disasters. The most common disasters that affect banana production in St. Lucia are high winds, hurricanes, and drought, although volcanic eruptions, earthquakes, and flash floods have been reported in the general area. Any of these disasters could affect banana production—and hence the flow of project benefits—or require additional expenditures beyond the estimated rise in costs of the project. The amount of damage would depend on the type and magnitude of the disaster. A shortfall in banana production would reduce crop revenues as well as labor income in the production and processing sector.

Disaster return frequencies are shown in table 4-2. Each of these natural disasters could have significant impacts on yields. Using data from a variety of sources, yield impacts were estimated for a typical disaster event. As shown in table 4-2, the natural disaster impacts range from 15 percent for a typical drought event to 90 percent for a hurricane. The impacts on yield would be greater if more than one disaster occurred in a given year. Droughts and tropical storms have similar return frequencies, occurring approximately once every six years (14 percent), but tropical storms have a greater damaging effect on yields.

For purposes of this analysis, the disaster events were assumed to be distributed independently. It was also assumed that disasters only affected the project by reducing yields. Although additional costs may be incurred as a result of a storm or drought, no information was available to quantify such changes in costs. From anecdotal reports, it appears reasonable to assume that the primary impact of disasters on the project's net benefits is through the impact on agricultural yields.

The effects of natural disasters on project economics were initially captured by using an historical distribution of crop yields. Data on banana yield for the Dennery Estate were available for 1970–84. The mean yield was 4.78 tons per acre with a range of 2.77 to 8.15 tons. A statistical test for upward trend in the data revealed no systematic trend, hence the variation was apparently due to weather-related shocks to the production system. The historical yields were used to generate a probability distribution from which random draws were generated for the risk analysis. The randomly drawn yields were used to calculate the benefits and costs of the project and to calculate a new internal rate of return for each random draw. This allowed a probability distribution to be estimated for the project's rates of return. The random number generation and benefit-cost calculations were carried out with a stochastic simulation program written by the author.

Once the base benefit-cost analysis was completed, disaster mitigation was introduced. A mitigation practice advocated by agricultural experts is the use of nematicides to strengthen the roots of banana plants by protecting the root system from parasites. This reduces the chance of the plants being uprooted by low to moderate windstorms, although the practice is not effective against hurricanes. The use of nematicides was estimated to increase establishment costs by EC$74 per acre and annual production costs by EC$270 per acre. The primary benefit of mitigation would be an increase in banana production in years with windstorms.

The historical probability distribution of banana yields was truncated to reflect the risk reduction afforded by the mitigation measure. The truncation involved cutting off the lower tail of the distribution, which reflected disaster-reduced yields.[7] This truncated distribution was then used to estimate a probability distribution of project net benefits with the mitigation measure.

Several risk-modified, benefit-cost methods were used to examine disaster mitigation for this case study. The results for one of the methods, mean-variance analysis, are reported in table 4-3. If mitigation was not included, the mean rate of return to the project was 29.5 percent. The coefficient of variation (standard deviation divided by the mean) was 69 percent. Including the mitigation practice reduced the mean rate of return to 27.6 percent but also lowered project risk. The coefficient of variation was lowered to 62 percent,

Table 4-3: Internal Rate of Return for an Agricultural Development Project With and Without Disaster Mitigation

Indicator	*With mitigation*	*Without mitigation*
Mean	0.295	0.276
Coefficient of variation	0.691	0.616

indicating that the investment in mitigation brought about the desired reduction in risk. A decision based solely on the average of project economic indicators might lead to a rejection of the mitigation measures since the mean rate of return to the project was lower with the measure. This underscores the importance of the added information on variability of project returns. Depending on the degree of risk reduction, planners or policymakers might be willing to trade lower expected return for lower risk.

Implementation issues

Natural disasters are a global concern because they affect such a large portion of the earth's landscape and population, but the management of natural disasters is one of several environmental concerns that remain to be integrated into development planning (Bender 1991). In many cases, development planners view disaster prevention and mitigation as unaffordable extras when they plan projects and programs (Anderson 1991). The international development community can do much to promote the integration of disaster considerations into planning efforts. Risk-modified, benefit-cost analysis is one tool to assist these efforts. Since it represents an extension of a widely used analytical tool, it has considerable potential for adoption. Furthermore, the results of risk-modified, benefit-cost analysis can be used to show policymakers and planners that disaster prevention or mitigation is often less costly than disaster recovery.

However, obtaining the requisite data for estimating probability distributions is challenging in many cases. Oftentimes, historical or episodic data are of insufficient duration to estimate reliably the probability of an event. Alternatively, subjective probability elicitation methods can be used, but many benefit-cost practitioners are unfamiliar with these techniques. In addition to the challenges of estimating the frequency and severity of a disaster, there is the need to translate these physical impacts into monetary terms. Some impacts require the use of nonmarket valuation methods. While such methods are increasingly applied in a developing-country context, the skills needed to do so are in limited supply. For these reasons, a full integration of disaster considerations into project economic analysis will require considerable investments to upgrade the skills of project analysts.

In developing countries, poverty and vulnerability to natural disasters often go hand in hand. This is due to population growth and continued modifications in environmental systems brought on by uncontrolled changes in land use (Kreimer and Munasinghe 1991). Low-income populations are often the hardest hit by natural disasters, and the slow pace of the ensuing disaster recovery measures may exacerbate existing income inequalities. Hence, disaster mitigation can have significant equity implications. The distribution of benefits from projects with and without disaster mitigation components can be quite different. While benefit-cost results are often reported in the aggregate, the methods described in this chapter can be used to generate net benefit estimates for different groups in a society. This information would provide assistance to those concerned with how development alternatives affect poverty. Disaggregating the economic impacts would also provide insights into the local, regional, and national implications of disaster mitigation.

Implications for sustainable development

Natural disasters are a major impediment to economic development and cause massive loss of life and property. The losses are significant to the countries where they occur and to the private and public investors in development activities. Yet, national and international development agencies often act as if their programs and natural disasters are unrelated. Investing in disaster mitigation can lessen damage and hasten recovery. By maintaining the momentum of development, protecting some of the most economically and environmentally vulnerable populations, and reducing damages to natural environments, disaster mitigation holds promise for helping to achieve the goals of sustainable development.

This chapter has shown a variety of ways in which information about natural disasters can be included systematically in the economic analysis of projects and programs. Because risk-modified, benefit-cost analysis has not been widely integrated into the project activities of development agencies, it is not possible to judge fully its potential effectiveness. An applied research effort combining experts from social and natural sciences should be initiated to develop a series of case studies to determine which of the methods described here would be most effective in project analysis. The case studies should be selected so as to gain experience from applying the methods in a variety of sectors and a variety of disaster vulnerabilities. Only after such experience is gained can the practical value of modified benefit-cost analysis be judged appropriately.

Notes

1. Frank Knight proposed in 1921 a distinction between risk and uncertainty that relied on the unquantified nature of the latter. This distinction was adopted by many succeeding writers. With the emergence of subjective probability assessment as a legitimate means of quantification, much of the modern literature, including this paper, uses the terms risk and uncertainty interchangeably.
2. This section draws on earlier work by Kramer and Florey (1987).
3. Until recently, analysts wrote their own programs for probabilistic benefit-cost analysis. However, spreadsheet programs now offer risk analysis add-ons that simplify the procedures. One example is the commercial package @RISK, which allows probability distributions to be specified for random variables used in the Lotus 1-2-3 or Excel spreadsheet programs.
4. Mean-variance analysis can be consistent with the theory of expected utility decisionmaking if one either assumes a quadratic utility function or assumes that returns have a normal probability distribution. Although these are rather strong assumptions, much of the risk and finance literature argues that such assumptions are not unreasonable approximations. See, for example, Levy and Markowitz 1979.
5. A potentially significant cost not included in these figures is the environmental cost of agricultural production in rolling terrain. Bananas do not have good soil-holding properties, so increased soil erosion is likely to occur when natural cover is removed to plant bananas. The project plan called for removing highly erodible land from

production, which could offset increased erosion from the expansion of banana production. In addition, the project called for ecological monitoring to determine the extent of environmental damage resulting from project activities. More research is needed to estimate environmental costs of agriculture in the study area, using methods such as the travel cost method, contingent valuation method, land price analysis, productivity analysis, and opportunity cost analysis.

6. An OAS report states that "Crop production is expected to remain the principal source of income for the rapidly increasing population of the Valley. The main opportunity for sustaining, if not improving, *per capita* income will be in the more intensive use of the land" (OAS 1985, p. 25).
7. The years with the three lowest yields were assumed to have been affected by high winds since a check of disaster records showed no drought or hurricane events in those years. The yields for those three years were replaced with the mean of the remaining year's yields. See Florey 1986 for additional details.

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