Chapter 4: **Results & Discussion**

4.1. Introduction

The study was designed to provide a framework for assessing the economic impacts of IPM CRSP activities in the countries where it operates. Such a framework could help the project evaluators to assess the programs in a short period of time with a limited budget. This chapter is intended to illustrate some of the concepts and procedures discussed in the earlier chapters. Four case studies were performed from Bangladesh and Uganda. Although the form of these case studies may be applied in other areas and circumstances, it should be noted that the actual data and findings can not be transferred to other localities. They should be worked out specifically for a given climatic zone, social and economic context. The first and second sections of the chapter describe the problem statements of the case studies and review the agricultural performance and potentials of Bangladesh and Uganda. The third section lays the theoretical grounds for the spatial classification. The fourth section presents sources of data and their limitations in the study. The fifth section illustrates the scope of the study. The sixth section outlines the results and their respective sensitivity analyses, and also discusses their implications. The two sets of case studies given below help illustrate the feasibility and functionality of the framework. The last section provides the concluding remarks about the methodology and the results.

4.2. Bangladesh

4.2.1. Background

The Asia-Pacific region annually produces more than 200 million tons of vegetables, accounting for about 49% of the world's vegetable production; China and India together account for about three-quarters of the region's vegetable production (Singh, 1990). Even though Bangladesh produces fewer vegetables in its overall production than China or India, its production for domestic consumption is substantial. Vegetables are important supplementary sources of food and nutrition. They are also one of the major sources of cash for small farmers. A wide variety of vegetables are produced in Bangladesh. These include *cabbage*, Chinese cabbage, cauliflower, radish, tomato, *eggplant (Brinjal)*, pepper and potato (BBS, 1995).

Bangladesh's vegetable farming industry uses a substantial amount and range of chemical pesticides. Spraying is done frequently, and dosages applied are in many cases higher than the recommended rates (Singh, 1990). Application of mixtures of chemicals is very common (Singh, 1990). According to FAO, the problems arising from overuse of pesticides in vegetables include development of pest resistance to pesticides, environmental contamination, increased health hazards to applicators, danger to consumers of high toxic residues on market produce, and rising production costs.

The development of IPM programs for vegetable pests in Bangladesh varies among different commodities. The Integrated Pest Management

Collaborative Research Support Program (IPM CRSP) in Bangladesh focuses mainly on eggplant, cabbage, cauliflower, and gourds. Different IPM technologies are being developed and employed for the production of these vegetables by the IPM CRSP. Two technologies will be analyzed and assessed to determine their potential benefits to the overall economy of Bangladesh and its environs.

4.2.2. Agricultural Policy & Performance

Bangladesh, a predominately agrarian economy, is characterized by small-scale, fragmented farming, employing primitive technology. It is one of the poorest and most populous nations of the world. The country has to support some 124 million people with a density of 800 persons per sq. km. The majority of the population lives in extreme poverty and widespread hunger. Though agriculture serves as the mainstay of the population, contributing about half of the GDP and employing two-thirds of the total labor force, the high population growth rate offsets increased agricultural production, thereby exacerbating the food deficit and poverty.

Bangladesh is one of the world's most densely populated nations, with a rapidly growing population and growing economic expectations. These factors place an enormous burden on agriculture in the country. The intensification of crop production programs with an emphasis on increasingly higher yields has resulted in more intensive fertilizer and pesticide use and unsustainable land

and water use (Raheja, 1995). Under such circumstances, hitherto minor pests have acquired the status of major pests and pest outbreaks have become more frequent (Raheja, 1995). Furthermore, the incidence of pesticide misuses, pest resurgence, and development of resistance are increasing (Flint, 1989). Pesticide misuse is also responsible for unacceptable levels of pesticide residues in marketed produce, health risks and contamination of aquatic and terrestrial ecosystems. Bangladesh is characterized by its large number of small-scale and subsistence farms. Even though there have been tremendous advances in agriculture in Asia, the spread of these advances in Bangladesh has been disappointing and a large number of these resource-poor farmers still remain unaffected by new technologies (Raheja, 1995).

Despite the hardships they face, an increasing number of Bangladeshi farmers are responding to new production opportunities by adopting more cost-effective biological technologies. In doing this, they are demonstrating a basic awareness of economic relationships vital to a successful developmental strategy for agriculture. The magnitude of adoption and the yield-increasing nature of the technology being accepted suggest that Bangladeshi farmers are moving the nation along the path of technical change. Innovations that increase yield are the appropriate economic response when land is scarce and labor is abundant as in Bangladesh. The demonstration of economic viability of new technologies is of particular importance given the strategic need to generate increases in factor productivity among a much broader base of farmers (Wennergren et al., 317).

One of the new approaches these farmers are adopting is IPM. IPM is now accepted as a rational approach to managing pests while potentially reducing the misuse of pesticides and preventing future environmental catastrophes. Bangladesh has now declared IPM as part of its agricultural development policy. The process of converting the concept of IPM into an operational approach has also been started, and over the years numerous IPM programs have been developed and implemented. Its rice and wheat industries have enjoyed substantial increases in yield using IPM technologies with assistance from FAO and other organizations.

Table 4.1: Production Trends of Brinjal & Cabbage in Bangladesh

Year	**Kharif Brinjal**		**Rabi Brinjal**		**Cabbage**	
	Area Planted (Acres)	Production (Metric tons)	Area Planted (Acres)	Production (Metric tons)	Area Planted (Acres)	Production (Metric tons)
1991	24415	53475	47135	132365	19850	69620
1992	24055	54190	47195	131060	20920	71070
1993	24190	57225	47700	132020	22000	76040
1994	23775	56170	47620	132050	22700	81390
1995	24775	59415	47180	128290	23930	90795
1996	25295	59845	47465	128900	24925	97440
1997	25980	61225	48030	130685	26425	106655

Source: *Yearbook of Agricultural Statistics of Bangladesh, 1997.*

4.3. Uganda

4.3.1. Background

Uganda's population growth rate is well over 4 percent per annum, resulting in the population almost tripling in 30 years (World Bank, 1993). This situation, combined with the reduction in the per capita index of food production and the less-than-required daily calorie supply, means that there will be continued pressure on resources to produce ever-larger amounts of food. Agriculture is also crucial to Uganda's economic development. Over 90 percent of Uganda's exports are agricultural in origin, with the large majority of the value being produced by coffee, tea, tobacco, and cotton. Thus, attempts to revitalize Uganda's economy will have to depend initially on agricultural production.

The need for intensifying agricultural production must focus first on food crops in order to meet domestic food consumption demands. The two most important food crops in Uganda, and in Africa, are bean and maize (World Bank, 1993). Bean and maize play a vital role in the economy and nutritional status of most African countries. Bean and maize are primarily produced for home consumption and are therefore important components in the household's diet. Uganda was the third largest producer of bean in sub-Saharan Africa for the period 1986-88 with 272,000 tons produced on 368,620 hectares (FAO, 1989). Intensification of agricultural production requires extensive use of agricultural inputs, such as fertilizers and pesticides. Fortunately, pesticide use tends to be low on food crops and local maize and bean cultivars are said to need little or no pesticide protection. Farmers have traditionally used local pest resistant varieties and cultural controls.

Unlike Bangladesh, the development of IPM technologies in Uganda for food crops focuses on improving existing biological and cultural controls, since use of pesticides is almost negligible. In fact, pesticide usage tends to be significant on only cash crops, such as coffee and cotton. Therefore, the IPM CRSP is developing IPM strategies that coincide with the growing demand for alternatives to pesticides and improving existing biological and cultural activities. IPM CRSP's research focus in Uganda is on primary food crops, such as bean, maize, sorghum, and groundnuts. Much of the research completed already concentrates on maize and bean. Numerous IPM strategies have been developed for these crops and they will be assessed to determine their potential impact on the overall agricultural economy of Uganda.

4.3.2. Agricultural Policy & Performance

Agriculture is the dominant sector of the Ugandan economy, accounting for more than two-thirds of the GDP, providing a livelihood for about 85 percent of the population, and supplying virtually the entire foreign exchange earnings of the country (95 percent between 1981-1989). In addition, agriculture contributes raw materials to agro-based industries, such as coffee processing, cotton ginning, teas and sugar processing, grain and saw milling. The sector is also the major source of government revenue – averaging 40 percent in recent years. Agriculture is therefore the key determinant of economic growth, employment, and welfare of the population.

Of the total land area of 237,000 square kilometers, approximately 79 percent is estimated to be cultivable with good to excellent agricultural potential, while only one-third of this is estimated to be in permanent use. With some of the best agricultural land in Sub-Saharan Africa, its moderate temperature and the adequate rainfall over most of the country (900 to 1200 mm per annum), Uganda has a strong base for agricultural development. Population density is low-averaging 57 persons per square kilometer- and although there are pockets of high population pressure, these are often a reflection of the productivity of the arable land resources.

The growth of the Ugandan economy is dependent on the agricultural sector. Not only is agriculture the major foreign exchange earner of Uganda, it contributes about 68 percent of the total GDP of the nation. Because agriculture plays such a vital role in the economy, there is a need to give incentives to boost the agricultural sector. Uganda has been gifted in its climate, as 85 percent of land is favorable for agriculture. The land is predominately occupied by small-scale farmers who produce 95 percent of the coffee, and 100 percent of the cotton, which are the major cash crops. The major food crops grown by these small holders include maize, beans, millet, groundnuts, sorghum, cassava, sweet potatoes, and bananas. Beans, maize, cassava, and sweet potatoes are substantially grown as the common staple foods. Bean and maize are widely grown as they can resist harsh conditions and can grow on a variety of soil types.

The Bean/Maize Sector

In Uganda, beans and maize have received a great deal of attention in recent years because of the need to expand and diversify the export base. Traditionally, beans and maize are produced as a food crop providing a source of protein for a substantial part of both the rural and urban populations. Beans and Maize became important subsistence and nontraditional crops in the 1970s and 1980s as marketing systems for cotton collapsed. These crops now rank among the priority cash crops because they are looked at as having great export potential, given the deficit countries surrounding Uganda and given the demand by food relief agencies that operate in Africa's eastern, central, and southern regions.

The current overall food security and national situation in Uganda with respect to beans and maize can be described as reasonably fair and favorably comparable with neighboring countries. However, the apparent national equilibrium of bean/maize supply and demand conceals considerable deficiencies in certain population groups and regions. In other words, bean/maize may seem somewhat available in adequate amounts at the national level, but are often insufficiently available to some population groups and regions. Table 4.2 present beans and maize production trends of the past ten years (1986-1996).

The beans/maize supply of Uganda comes from domestic production, which is widely scattered all over the country. However, Jinja, Mbale, Iganga, and Kapchorwa districts in the east, and Masaka, Kabale, and Kassese in central and southwest, accounted for about 50 percent of the total area planted in 1989 (Venagus, 1992). Viewed on a national scale, bean/maize are typically produced on small, subsistence, and semi-commercial farms. Studies carried out for the past two decades show that about 20 percent of the growth in production comes from area increase (cropping pattern) and about 80 percent from higher yields per hectare (better cultural practices and agro-climatic conditions). Because yield increase plays a major role in the growth of bean/maize production, policies to sustain yield growth will be crucial for the future. A number of pests and diseases attack bean/maize. Though cultural practices such as crop rotation and use of clean seed have been effective control mechanisms, a more integrated pest control strategy is needed to sustain production.

Table 4.2: Bean and Maize Production trends in Uganda

Year	Bean		Maize	
	Area Planted (Hectares)	Production (Tones)	Area Planted (Hectares)	Production (Tones)
1986	396	267	322	322
1987	373	299	307	357
1988	445	338	345	440
1989	480	389	430	624
1990	495	396	401	602
1991	570	383	420	567
1992	536	402	438	657
1993	552	428	503	804
1994	574	378	563	850
1995	600	390	571	913
1996	615	234	584	759

Source: Statistics Department, Ministry of Finance, Planning, and Economic Development, 1998.

4.4. The Agro-ecological Basis of the Zonal Classification

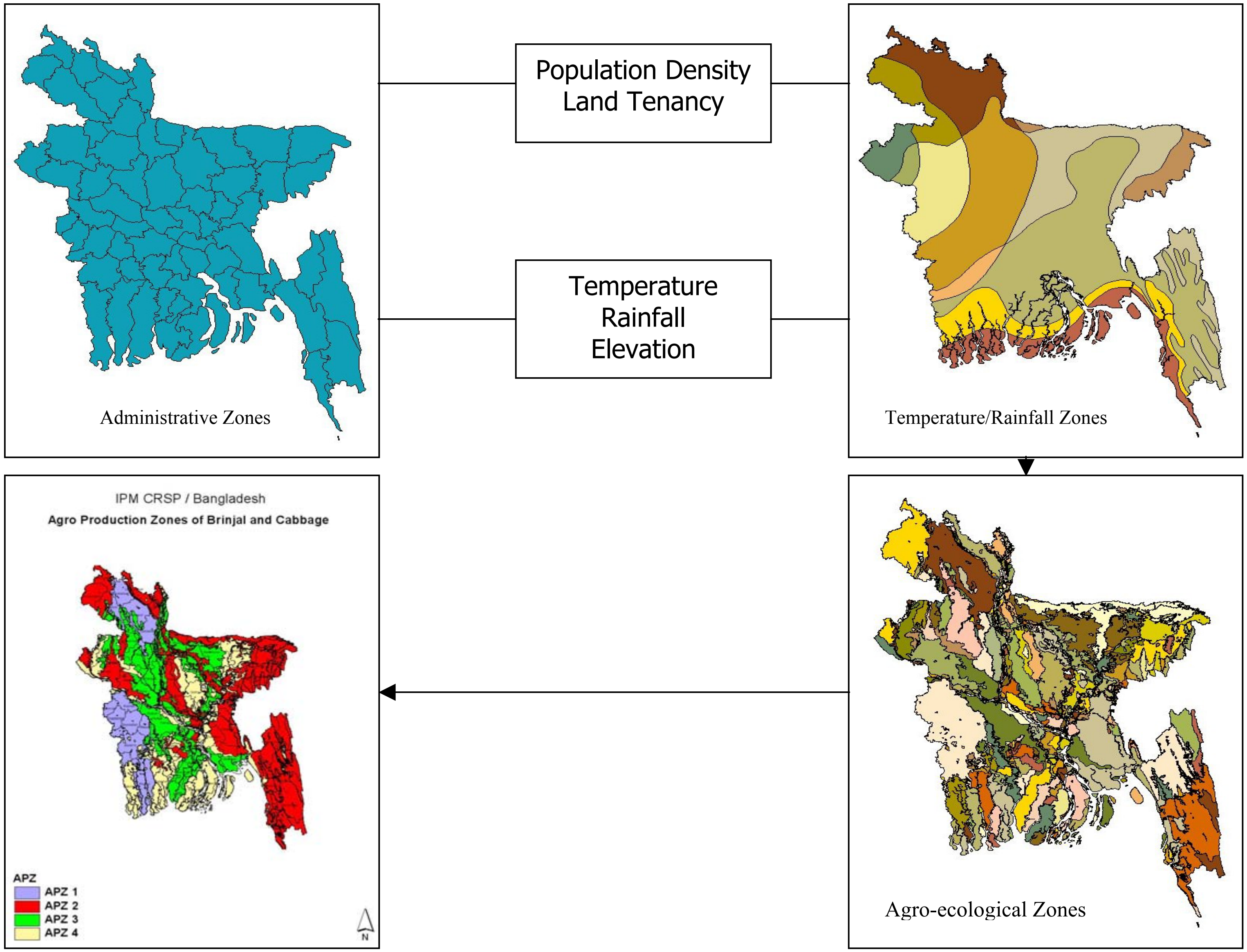
Many commodities, and individual technologies within a commodity sector, are particularly well suited to specific production environments. Within the same country, there is a tremendous diversity in agricultural production systems (Mills, 1997). Agro-climatic conditions are a major factor in this diversity and can be used to demarcate areas where the expected impact of specific agricultural technologies will be fairly similar in terms of yield. Traditional models of agro-ecological characterization have relied on cartographic reproduction of static zones based on fixed crop-environment relationships. However, the traditional models pose several limitations. For example, they define a single set of zones applicable to all crops. The zones are too general to reflect the range of sensitivity of most crops to environmental and other variables.

Fortunately, the emergence of GIS has made it possible to delineate agro-climatic zones with greater precision, especially by allowing many 'layers' of spatially referenced data to be integrated into one digital database. As a result, this study employed a GIS-based digital framework to characterize agro-climatic zones. The framework possesses several advantages that enable it to overcome the limitations of the traditional static systems. One of the most important advantages with this dynamic system is that it can be specific to a given crop or ecosystem. This makes it possible to evaluate a given zonal classification based on production trends or biophysical traits (Corbett, 1998). Also, this kind of dynamic classification can be taken even further by integrating agro-climatic data with socio-economic information to evaluate the implications of institutional policies. Moreover, the ability to reproduce boundaries digitally allows for subsequent improvements in the classification as researchers gain a better understanding of crop-environment interactions or acquire more data (Corbett, 1998).

Data Sets: As GIS technology is a recent phenomenon; developing countries may not have the digital data infrastructure needed to perform the spatial analysis. Even though, the FAO (1997) and CIAT (1999) have done some work in the GIS field in Bangladesh and Uganda, respectively, the spatial framework designed for this study required a specialized format for data that were not readily available. The study had to rely on GIS expert opinions about the key environmental determinants of commodity production and generate raw data by making some spatial assumptions.

Zonation Methods: The biophysical suitability of locations to support specific commodities and technologies depends on many factors. Key among those are temperature, elevation, and rainfall. These climatological factors interact with local characteristics, such as soil texture and population density, to determine agricultural potential (Alston et al., 2000). Using the above factors as zoning criteria, the researcher identified large spatial units that encompass numerous agro-climatic and socio-economic traits that should have homogenous biophysical effects on production. Following several mapping iterations, four agro-production zones (APZ) were identified for all of the crops. The data sets were processed using a three-stage sequence of spatial classification procedures to develop crop-specific agro-production zones. These classification procedures and APZ definitions are presented on Tables 4.3 & 4.4 and Figures 4.1 & 4.2.

Figure 4.1: The Spatial Classification of Agro-production zones of Bangladesh



Zones	Population Density (Inhabitants/Km^2)	Land Tenancy (%*)	Production (Metric Tons)	
			Brinjal	Cabbage
APZ1	200-600	50-60	14-27	7-12
APZ2	10-200	>60	6-13	4-6
APZ3	600-1000	40-60	2-5	0.7-3
APZ4	1000-2000	<40	0-1	0-0.6

***Tenant household as % of farm households**

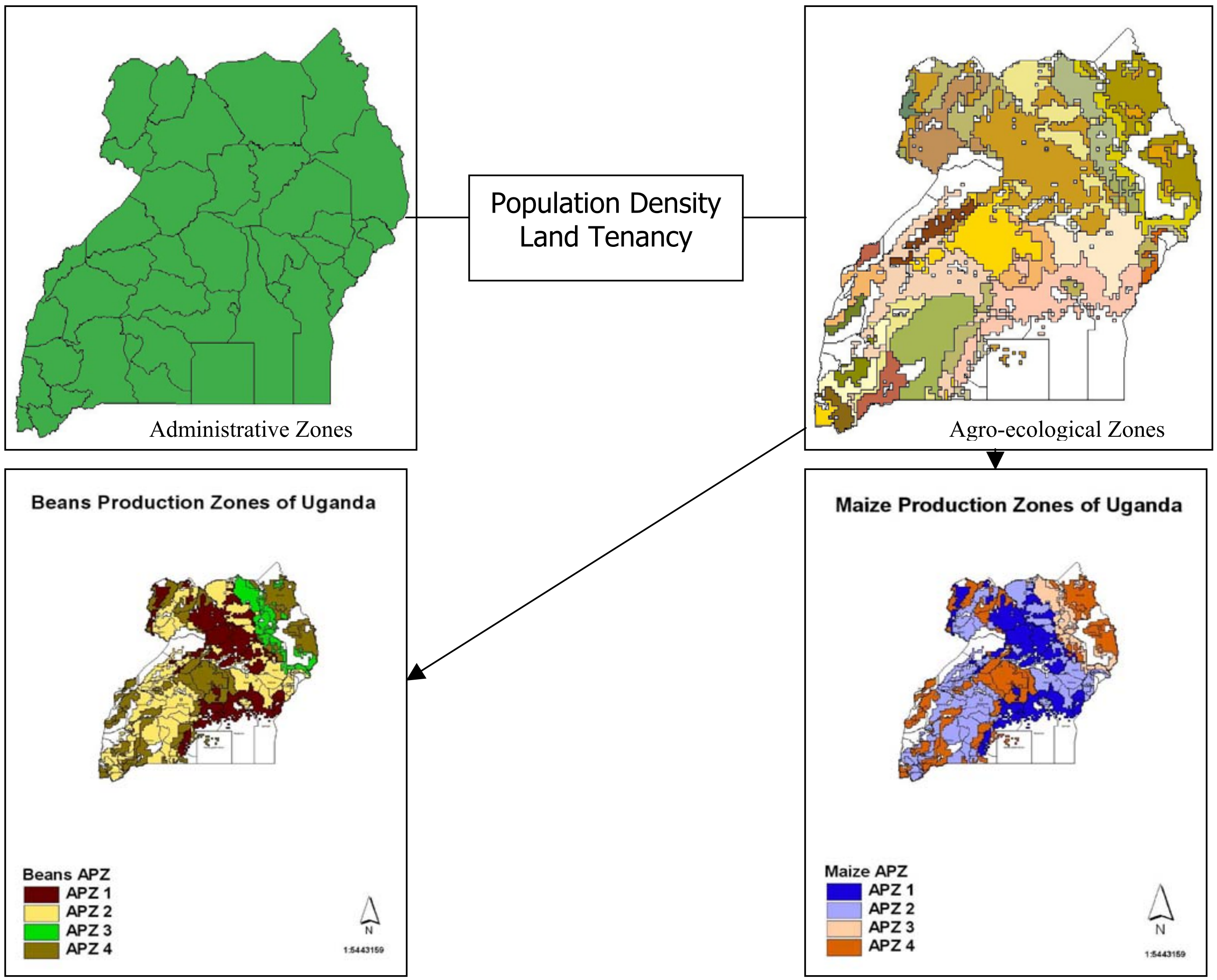
Table 4.3: Classification of Bangladesh's Agro-ecological zones according to socio-economic data

Zones	Population Density (Inhabitants/Km^2)	Land Tenancy (%*)	Production (Metric Tons)	
			Beans	Maize
APZ1	100-500	<40	69-138	50-131
APZ2	1000-2000	40-50	24-68	20-49
APZ3	10-100	>60	10-23	10-19
APZ4	500-1000	50-60	0-9	0-9

***Tenant household as % of farm households**

Table 4.4: Classification of Uganda's Agro-ecological zones according to socio-economic data

Figure 4.2: The Spatial Classification of Agro-production zones of Uganda



4.5. Data Sources and Limitations

This study contains an extensive amount of information. However, the nature of economic impact assessment necessitates periodic revisions and updates of production budgets, price information, experiment data, and adoption profiles. We suggest that the analysis presented in this study be treated as a framework of analyzing more specific data and situations in the future. The Agricultural Marketing Directorate, the Department of Planning and Statistics of Uganda, and the Bank of Uganda provided published data such as production, consumption, and prices. Information in regard to price policies and elasticities are acquired from previous studies. All data in relation to estimation such as expected per unit cost reduction, probability of technology change, and expected level of adoption were obtained through questioning scientists involved in the development or dissemination of the technology.

The spatial distributions of eggplant and cabbage prices in Bangladesh and bean and maize prices in Uganda were empirically estimated from 1996 and 1997 monthly retail price data provided by their respective national bureaus of statistics. The markets were spatially referenced in order to allocate all areas within Bangladesh and Uganda to the nearest markets (Mills, 1997).

There are three primary data limitations in performing the type of analysis presented here. First, due to the nature of ex ante research assessment, the study depends heavily on secondary data and experiment data. Historically, experiment data are not reliable as the quality of the data relies upon the quality of the researchers involved in collecting it. Second, the ex ante parameters of technology generation and adoption must be based on the subjective opinion of scientists and researchers. The potential bias of scientists due to their vested interest in the outcomes of estimating the benefits may compromise the reliability of their estimates.

4.6. Site Description

Prior to discussing the results of case studies, it is necessary to provide a brief description of the IPM CRSP experiment sites and their general physical and social conditions. The study will focus on one key site Kashimpur of Gazipur district in Bangladesh; and on two primary sites, Iganga and Kumi districts in Uganda.

Bangladesh: Kashimpur union is situated in Gazipur district within Dhaka division at the heart of Bangladesh. Gazipur district has an area of 1,577.4 km^2 of which 1,215 is highland area. The Kashimpur union is located within the highland area, which normally avoids the flooding of between 180 and 300 cm deep during the flood season (BBS, 1997). Kashimpur has a long growing season and generous rainfall that is suitable to cultivation of numerous crops. The average annual rainfall for Gazipur district is 73 inches – average for Bangladesh (BBS, 1997). Such favorable physical and meteorological conditions make Kashimpur union a very good candidate for the cultivation of vegetable crops as well as other winter crops.

Nevertheless, favorable physical conditions are not the only part of the reason why the experiments were undertaken at this location. The determining factor for the success of IPM research is the commitment of the local community leaders and farmers to continually search for more viable paths to increasing productivity and environmental protection. Kashimpur farmers have been very active in promoting alternative means of pest management practices and have taken various steps in that direction.

Uganda: Iganga and Kumi districts were selected for several reasons. Iganga district (longitudes 33^0 22′ E to 33^0 97′ E, latitudes 0^0 17′ S to 0^0 75′ N) has an area of 1,3144 km^2 of which 4,823 is land area (Wortmann, 1999). Elevation in the district ranges from 1,070 to 1,166 meters above sea level. The average annual mean temperature is 21^0C. Rainfall is bimodal (February-July and August-December), with an annual total ranging between 1,250 and 2,200 mm. Two Agro-ecological zones cut across the district: 1. The southern and western tall grasslands, where perennial and annual crops are produced, mainly in mixed farming systems, and 2. The northern and eastern short grasslands, where annual crops are produced, mainly in mixed farming systems (UBS, 1997). Iganga district is dominantly rural, with almost 96% of the populations living in the rural areas, and agriculture is the main economic activity. The main food crops are finger millet, maize, sorghum, rice, bananas, sweet potatoes, cassava, beans, simsim, and field peas. Maize and beans are the major subsistence and commercial crop. The districts account for about 15% of the maize and beans produced in Uganda (Wortmann, 1999). The two districts' farmers serve both the fresh and dry grain markets in the urban centers of Iganga, Jinja, and Kampala.

Figure 4.3 Gazipur District, IPM CRSP/Bangladesh experiment site

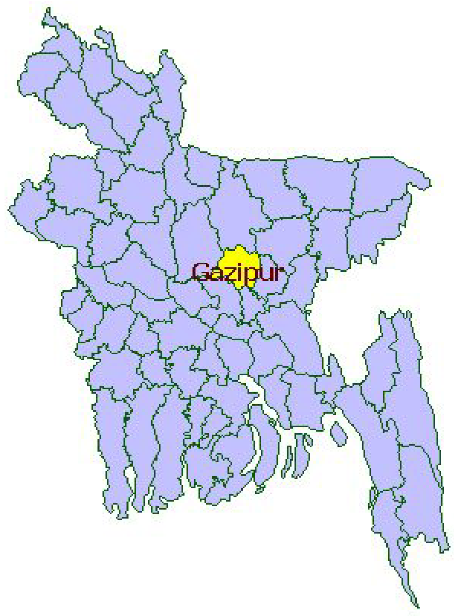
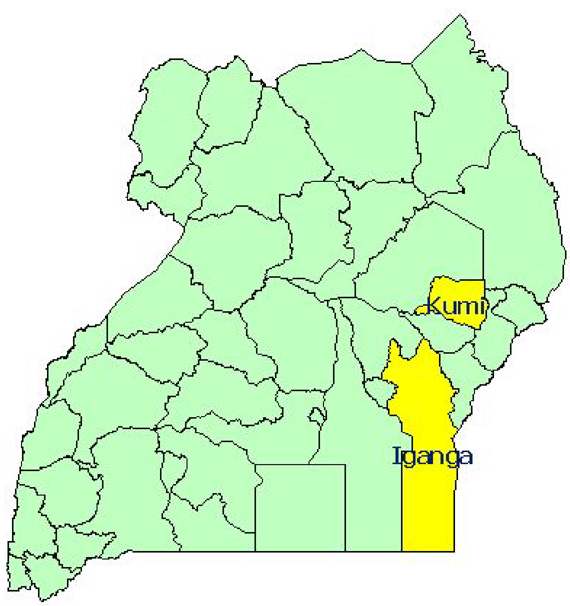


Figure 4.4 Kumi and Iganga Districts, IPM CRSP/Uganda experiment sites



4.7. Results, Discussion, and Sensitivity Analysis

A multiperiod, multiple interlinked market version of the basic model of economic surplus described in chapter three was used to estimate the benefits of two IPM technologies in each of Bangladesh and Uganda. The full model specification follows the multimarket model described in Appendix 5.1.2 of Alston et al. (1995). The model accounts for the dynamic elements of IPM research, including demand for commodities as a result of population growth and variable prices across production zones.

Prior to the analysis, the researcher developed a set of baseline estimates of the effects of exogenous shifts in demand and supply on equilibrium prices and quantities, absent technical change. Also, the adoption profile, probability of adoption and probability of success of IPM technologies were elicited for the commodities considered in this study. The adoption profile considers the year research begins, the year of adoption, expected maximum adoption rate, and year when technology begins to depreciate.

The model was solved recursively using DREAM (IFPRI, 2000). The next two sections present the estimated research-induced changes in producer and consumer surplus in Bangladesh and Uganda, respectively. These results represent the aggregate of the direct research impacts for each zone and the indirect impact through research-induced price changes in other commodity production and consumption zones.

The impact of IPM CRSP research activities on Bangladesh and Uganda markets are simulated over a thirty-year period discounted at 5%. The following sections present results from various simulations, designed to represent alternative approaches to incorporating information about knowledge spillovers into our regional commodity supply and demand model. The model simulates prices and quantities and present values of economic surplus (benefits to producers, consumers and in total) for each country and for the zonal and sub-zonal aggregates, for each scenario of interest. It is the economic surplus effects of country-specific and AEZ-specific research-induced supply shifts, in particular the distribution of those effects between producers and consumers and among zones, that are the focus of this study.

Bangladesh: Table 4.5 reports the basic data used to define the baseline simulations. This table includes the base quantities produced and consumed, and average price of commodities for the aggregate economy. It also includes the price elasticities of supply and demand, and population growth rate defining the underlying growth of rate of demand. Due to lack of sufficient data, demand for each production zones was not constructed. Instead, we have resorted to an aggregate demand function that represents an average consumption function for the whole country. Note also price elasticities for both commodities were assumed to be the same since there were no established elasticities for cabbage at this point of our research.

Zones	Quantities (T)		Price	Price Elasticities		Demand
	Supply	Demand	($/T)	Supply	Demand	Shift (%)
Brinjal						
APZ1	72,917		233	0.13		
APZ2	59,347		301	0.13		
APZ3	47,627		275	0.13		
APZ4	9,458		253	0.13		
Bangladesh	191,910	191,910	259	0.13	-0.2	3
Cabbage						
APZ1	30,629		94.32	0.13		
APZ2	40,829		82.65	0.13		
APZ3	21,127		96.73	0.13		
APZ4	9,870		80.95	0.13		
Bangladesh	108,255	108,255	92.18	0.13	-0.2	3

Table 4.5: Base Data for DREAM Simulation - Bangladesh

Table 4.6 summarizes the overall structure of the simulations and describes the parameters used to construct these simulations. These parameters were obtained from expert opinions gathered through questionnaires. The content and structure of the questionnaires are presented in the Appendix at the end of this thesis. Usually, these figures are the result of summarized and averaged calculations among the several responses elicited from questionnaires. However, in the case of Bangladesh, there was only one expert opinion taken for each of the commodities. This can pose a serious implication on the validity of the research findings. The sensitivity of the results is discussed in detail in the section following the discussion of the results.

Technology/Parameters	APZ 1	APZ 2	APZ 3	APZ 4
Neem Leaf Powder for Brinjal				
Research Lag (years)	2	2	2	2
Yield Change (%)	40	25	30	40
Cost Change (%)	20	30	20	23
Success level (%)	80	50	70	80
Adoption Level (%)	50	25	50	60
Max. Adoption (years)	5	7	6	5
Depreciation (years)	17	17	18	19
Complete Depreciation (years)	28	28	28	28
Hand Weeding for Cabbage				
Research Lag (years)	2	2	2	2
Yield Change (%)	5	2	5	5
Cost Change (%)	-50	-30	-50	-50
Success level (%)	90	70	85	90
Adoption Level (%)	60	40	60	70
Max. Adoption (years)	5	7	5	5
Depreciation (years)	17	17	18	18
Complete Depreciation (years)	20	20	20	20

Table 4.6: Parameters elicited from expert questionnaires for Bangladesh

Table 4.7 summarizes the results of the economic surplus analysis for two management strategies: Neem leaf powder to control soil-borne disease in Brinjal production and two hand weedings at 15 days after transplanting (DAT) and 45 DAT to control weeds in Cabbage production. These results represent the aggregate of the direct research impacts for each zone (Figure 1). A real discount rate of 5% is used. The simulated changes in total surplus and its producer and consumer components vary markedly across research themes and target zones.

Both management strategies have positive effects on both producer and consumer groups. There are, however, significant differences in the absolute amounts of benefits that can be realized.

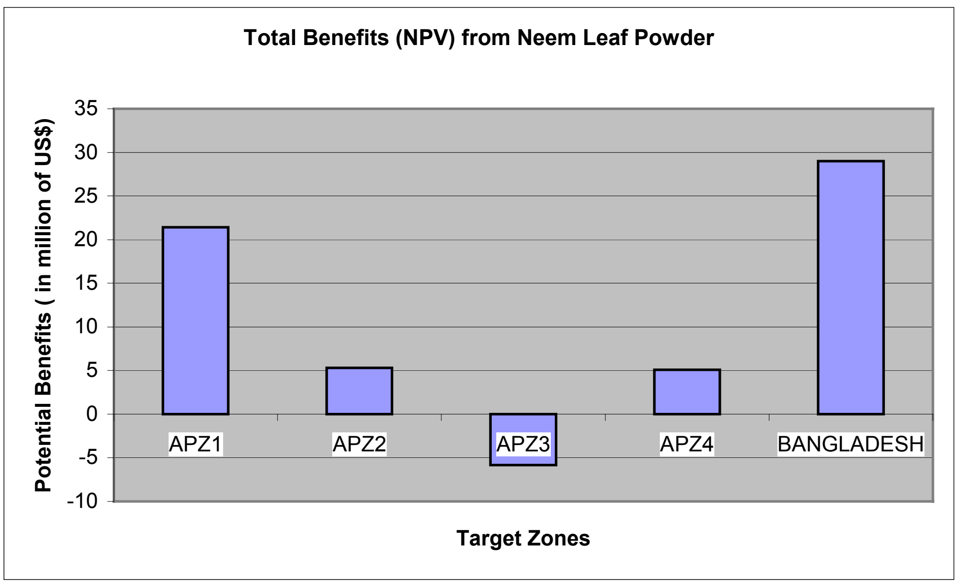
For Brinjal, APZ1, where the experiments are performed, has the highest NPV value. This is attributed to the zone's high concentration of Brinjal production and strong market outlet. APZ2 and APZ4 have very similar welfare gains due to market structure similarities. The net present values for APZ2 and APZ4 are $5.3 million and $5.1million, respectively. As for APZ3, the NPV is negative (-$5.8 million). Despite APZ3's welfare loss, the aggregate benefit to the entire country is significant. The net present value for Bangladesh measures as $29 million and the internal rate of return (IRR) is 684%.

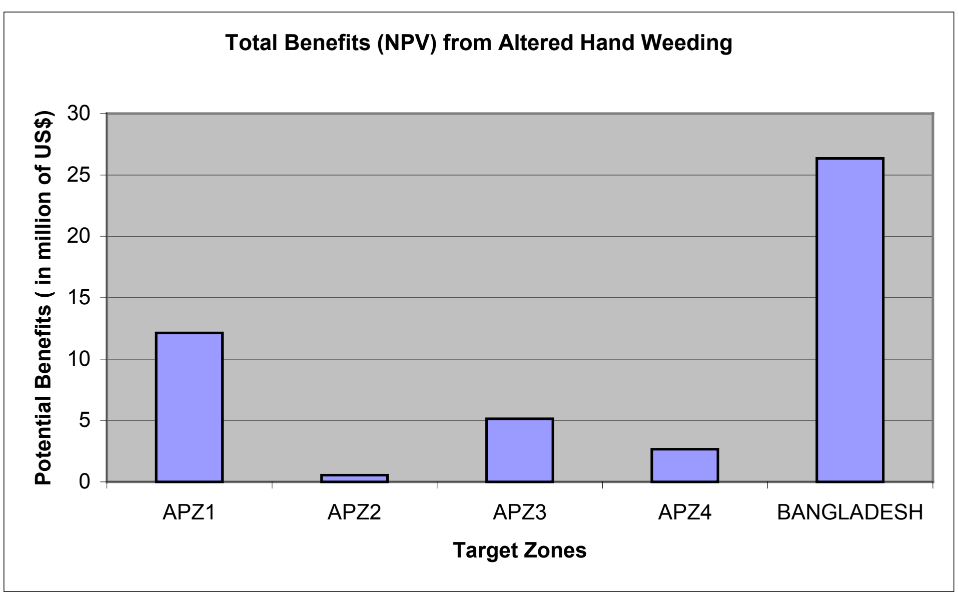
For Cabbage, APZ1 could receive a substantial welfare gain due to the introduction of altered hand weeding. In parallel to Neem leaf powder, hand weeding also gives the highest estimate of NPV ($12.1 million) in APZ1 relative to the other zones. APZ2, APZ3, and APZ4 have NPVs of $0.6 million, $5.1 million, and $2.7 million, respectively. The overall welfare gain from hand weeding in Bangladesh is $26.4 million with an IRR of 696% over the next thirty years. A summarized graphical representation of the results is provided on Figure 4.5.

Table 4.7: NPV and IRR of Total Economic Surplus estimates in Brinjal and Cabbage pest management strategies

Geographic Area	**Adoption Rate (%)**	**Research Cost ($)**	**NPV ($)**	**IRR (%)**
Brinjal: Neem leaf powder				
APZ1	50		21,406,097.0	
APZ2	25		5,314,639.8	
APZ3	50		-5,842,381.4	
APZ4	60		5,102,261.9	
Bangladesh	47	25724	29,080,134.6	684
Cabbage: hand weeding				
APZ1	60		12,124,072.63	
APZ2	40		562,978.5	
APZ3	60		5,145,238.4	
APZ4	70		2,663,559.6	
Bangladesh	59	21387.50	26,359,077.09	696

Figure 4.5: Graphical Representation of Potential Benefits





Sensitivity of Results

In the analysis, there are certain parameters involved that are subject to uncertainty because ex-ante studies rely heavily on the researchers' projections of yields, costs, and adoption rates. Therefore, model calculations were carried out with different values of key variables. Modifications of the per-unit-cost reductions, expected yield change, and the technology adoption rates can influence the magnitude of total benefits (Qaim, 1999). Thus a sensitivity analysis was performed to find out the source of uncertainties and to mitigate them wherever possible (See Table 4.8).

Adoption Rates: As discussed earlier, inaccurate technology adoption rates in economic surplus analysis can give rise to inflated or understated benefit estimates. The simulation allowed the effects of adoption levels to change by reducing the rates by about 80%. Relative to the base case, the range of reduced adoption rates served to decrease both the consumer and producer surplus, decrease total benefits, and in turn decrease both the NPV and IRR significantly.

Cost & Yield Changes: the cost and yield change structure was adjusted in another sensitivity exercise. Decreasing the yield change and increasing the cost change independently reduced the estimated aggregate supply shift. These cost & yield structures served to decrease consumer and producer surpluses. The NPV's and IRR's are significantly lower than in the baseline case because the reduced magnitude of the supply shift has decreased the amount of benefits directed to both consumer and producer groups.

Scenario		**NPV (US$ in millions)**	**IRR (%)**
1. Baseline			
Neam Leaf Powder		*29*	*684*
Hand Weeding		*26*	*696*
2. Lower Adoption Rate			
Neam Leaf Powder	*12*	*15*	*442*
Hand Weeding	*10*	*16*	*463*
3. Cost and/or Yield Change			
Neam Leaf Powder	*15*	*14*	*487*
Hand Weeding	*15*	*15*	*502*

Table 4.8: Summary of Sensitivity analysis

Uganda: Table 4.9 reports the basic data used to define the baseline simulations. This table includes the base quantities produced and consumed, and average price of commodities for the aggregate economy. It also includes the price elasticities of supply and demand, and population growth rate defining the underlying growth of rate of demand. As in the case of Bangladesh, an aggregate demand function is used to project total consumption of each commodity in Uganda due to lack of sufficient data at the zone level. The baseline scenario defines supply elasticities of 0.63 and 0.5 for beans and maize, respectively. Demand elasticities for beans and maize were set at a more inelastic value of -0.7 and -0.5, respectively. These elasticities are typical for food commodities in Uganda.

Zones	Quantities (T)		Price ($/T)	Price Elasticities		Demand
	Supply	Demand		Supply	Demand	Shift (%)
Beans						
APZ1	72,851		309	0.63		
APZ2	60,015		512	0.63		
APZ3	56,824		356	0.63		
APZ4	48,527		403	0.63		
Uganda	269,795	221,000	392	0.63	-0.7	3
Maize						
APZ1	60,213		221	0.5		
APZ2	56,897		272	0.5		
APZ3	49,532		328	0.5		
APZ4	33,569		295	0.5		
Uganda	223,105	216,405	265	0.5	-0.5	3

Table 4.9: Base data for DREAM Simulation - Uganda

Table 4.10 summarizes the overall structure of the simulations and describes the parameters used to construct these simulations. These parameters were obtained from expert opinions gathered through questionnaires. The content and structure of the questionnaires are presented in the Appendix at the end of this thesis. Usually, these figures are the result of summarized and averaged calculations among the several responses. However, in the case of Uganda, there were only four expert opinions available for each of the commodities. This can pose a serious implication on the validity of the research findings. An explanation for discrepancies can be found in the sensitivity analysis section of this chapter.

Technology/Parameters	APZ 1	APZ 2	APZ 3	APZ 4
Seed Dressing				
Research Lag (years)	3	3	3	3
Yield Change (%)	50	45	10	50
Success level (%)	90	88	50	80
Adoption Level (%)	50	48	20	50
Max. Adoption (years)	5	6	7	5
Depreciation (years)	17	17	18	19
Complete Depreciation (years)	28	28	28	28
Longe-1 variety				
Research Lag (years)	3	3	3	3
Yield Change (%)	60	50	50	50
Success level (%)	60	60	40	60
Adoption Level (%)	40	30	30	20
Max. Adoption (years)	10	11	11	12
Depreciation (years)	17	17	18	18
Complete Depreciation (years)	20	20	20	20

Table 4.10: Parameters elicited from expert questionnaires for Uganda

The estimated economic surplus ratios, net present values, and internal rate of return in investments in IPM CRSP activities for the commodities considered in this study are shown in Table 4.11. Any increase/decrease in output or decrease/increase in cost will cause the supply curve to shift downward/upward. This shift in the supply curve will have a corresponding effect the overall welfare of the society. Table 4.11 summarizes the results of the economic surplus analysis for two management strategies for bean production (seed dressing with endosulfan to reduce bean fly symptoms compared to either

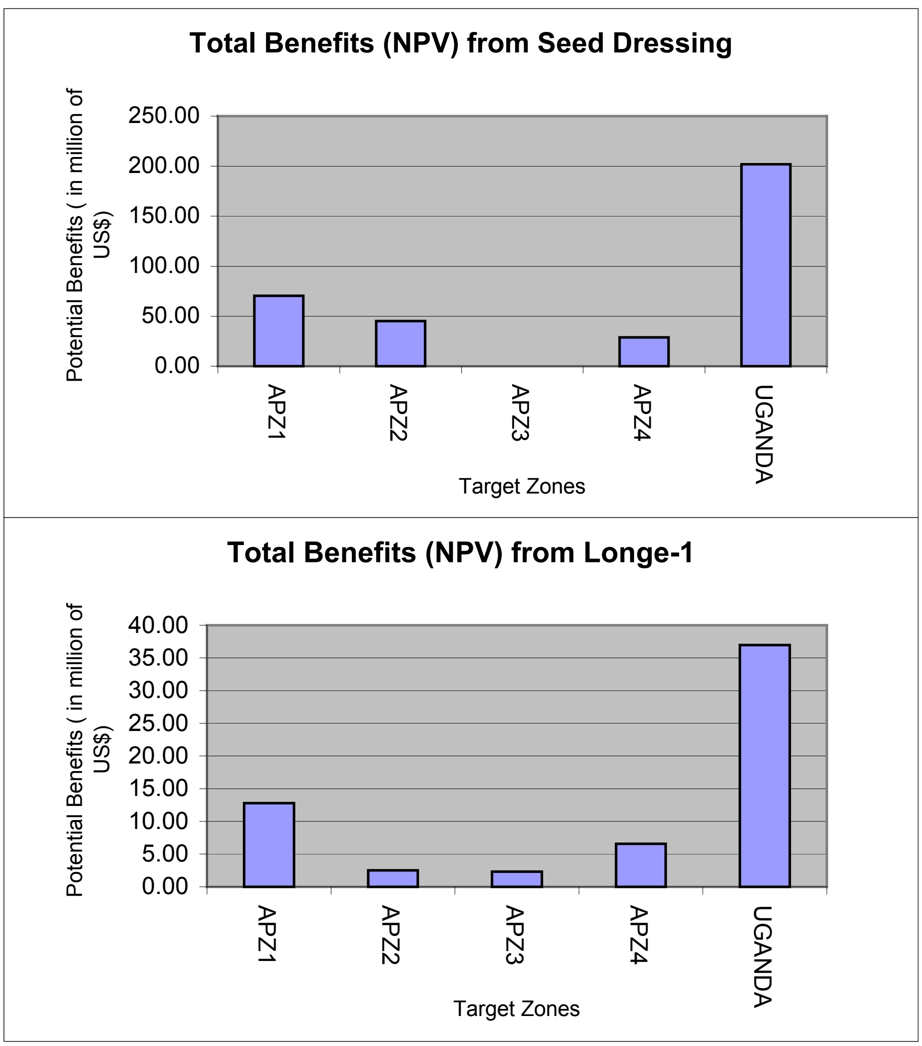
Diazinon or Benlate) and maize production (Longe-1 is an improved variety that is more resistant to maize streak virus and higher yielding compared to the local variety). Note that IPM CRSP did not develop Longe-1. It only promoted Longe-1's high resistance to maize streak virus. Thus, the evaluation done in this study encompasses Longe-1's overall benefits since its inception. Figure 4.1 and 4.2 provide a benchmark to showcase how the welfare gains are distributed across Uganda for each crop. In all of the four zones, both management strategies have positive effects on the different producer groups and consumers alike. There are, however, significant differences in the absolute amounts of benefits that can be realized according to the different assumptions made by the experts.

Note that APZ1 is treated as the host or technology innovator area where spillovers are transferred to the other zones. Also, due to lack of consumption data for each zone, the model was solved using one aggregate demand function for Uganda against each zone's supply function. Therefore, internal rate of return can only be solved for the aggregate economy. For seed dressing, the net present values (NPVs) are \$70.2 M for zone 1, \$45 M for zone 2, \$0.1 M for zone 3, and \$28 M for zone 4. For longe-1 variety, the NPVs are \$12 M for zone 1, \$2.5 M for zone 2, \$2.3 M for zone 3, and \$6.6 M for zone 4. The aggregate internal rate of return (IRR) is 250% over the next thirty years. A summarized graphical representation of the results is provided on Figure 4.3. All figures seem unreasonably high for long-term technology projects. The reasons for such discrepancies are discussed in detail in the next section.

Table 4.11: NPV and IRR of Total Economic Surplus estimates in Beans and Maize pest management strategies

Geographic Area	Adoption Rate (%)	Research Cost ($)	NPV ($)	IRR (%)
Beans: seed dressing				
APZ1	50	13340.00	70,274,112.60	
APZ2	48		45,156,287.40	
APZ3	50		10,854.60	
APZ4	50		28,816,083.00	
Uganda	49		202,092,044.70	250
Maize: Longe-1 variety				
APZ1	40	16762.50	12,770,643.40	
APZ2	30		2,511,841.80	
APZ3	30		2,289,420.50	
APZ4	50		6,563,705.80	
Uganda	38		36,951,845.20	250

Figure 4.4: Graphical Representation of Potential Benefits in Uganda



Sensitivity of Results

The very limited information obtained from the questionnaires forced us to make many assumptions about the magnitude of variables. To address these data gaps, the researcher carried out a series of sensitivity analysis over the results. In particular, assumptions about adoption levels, cost and yield changes, and supply/demand elasticities were examined. Due to extreme estimates by some respondents, all estimates of NPVs and IRRs appear unreasonably high. Thus, sensitivity analysis was conducted, similar to that performed for Bangladesh. The main estimates in question are adoption rates and expected yield and cost changes. The outcome of the sensitivity analysis in this section is identical to that in Bangladesh. As expected, the gain in total economic surplus change is proportional to variations of these two parameters. The benefit partition between producers and consumers remains unaffected. Although the influence on the IRRs is significant, the overall profitability of both technologies (seed dressing & longe-1 variety) is not jeopardized even with a significant percentage reduction of either per unit cost or adoption rates. The IRRs would still be higher than the opportunity cost of financial resources, assumed at 5 percent. When a range of adoption rates (5%-20%) is tested in the simulation, the consumer and producer surpluses decrease substantially relative to the base case. Also, reducing the expected yield and increasing the cost change independently and jointly served to decrease the total benefits. Both scenarios affect the magnitude of the NPV and IRR significantly. A summary of the sensitivity analysis is illustrated below in Table 4.12. The sensitivity results imply that technology adoption rates and estimates of cost/yield changes should be given an extra emphasis to produce reliable results and to strengthen the working model.

Scenario		NPV (US$ in millions)	IRR (%)
1. Baseline			
Seed Dressing		*202*	*250*
Longe-1		*36*	*250*
2. Lower adoption rate (%)			
Seed Dressing	*12*	*161*	*127*
Longe-1	*10*	*21*	*130*
3. Cost and/or Yield Change (%)			
Seed Dressing	*15*	*136*	*109*
Longe-1	*15*	*17*	*102*

Table 4.12: Summary of sensitivity analysis-Uganda

In general, the sensitivity analysis in both sections underlines the robustness of the framework and gives caution to the precision of the results. The results of this study are only as good as its underlying assumptions. Particularly, rates of return generated in this study cannot be strictly compared with results from ex-post analysis. The latter have the benefit of incorporating information on observed technology generation and adoption. Economic surplus and GIS models do not make decisions. They only provide information, which can be used to help arrive at a consensus on strategic priorities.

4.8. Conclusions

The goal of the case studies was twofold: To illustrate the functionality of the framework, and to estimate the aggregate benefits of specific IPM CRSP induced technologies in Bangladesh and Uganda. This kind of structured framework provides scientists in IPM programs with a better understanding of the environment for technology development (Mills et al., 1998). The classification of agro-production zones helps identify areas associated with key biophysical parameters for the specified crops. The zoning scheme also allows researchers to examine potential spillovers to other research centers in the region. The ex-ante research benefits estimated in these two case studies should be compared with current research priorities of the IPM CRSP. Consistent results can help IPM CRSP refine its research agenda and make a coherent argument about its potential contribution to national agricultural developmental objectives.