ASSESSING THE SOCIOECONOMIC IMPACT OF PARTICIPATORY PLANT BREEDING OF BEANS IN TWO REGIONS OF HONDURAS

By

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ABSTRACT

ASSESSING THE SOCIOECONOMIC IMPACT OF PARTICIPATORY PLANT BREEDING OF BEANS IN TWO REGIONS OF HONDURAS

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This study presents evidence about the strengths and weaknesses of the participatory plant breeding (PPB) projects in two regions of Honduras, empirically estimate the benefits and costs of PPB to farmers, and generate recommendations for successfully scaling up the PPB methodology. Results from a farm-level survey in 2006 in two regions of the country show that one of the most important strengths is that many PPB varieties have been adopted through the communities. PPB varieties were planted in 32% of the bean area while conventionally bred (CPB) varieties were planted only in 4% of the bean area. One of the most important weaknesses is that the project is technologically and financially dependent on Zamorano and NGOs. A single-equation linear regression model was estimated to evaluate factors associated with differences in farmers' yields. Both PPB and CPB varieties yielded more than traditional varieties. Farmers who planted a PPB variety obtained 20% higher yields than farmers planting a traditional variety and the economic impact of PPB varieties was 192% larger than that of CPB varieties. The net present value of PPB in Honduras from 1999 to 2018 is $969 and the rate of return is 10.73. To scale up PPB, stakeholders need to select CIALs with different environmental conditions than CIALs already implementing PPB, develop PPB varieties with higher yield advantage, and increase efforts to promote the use of PPB varieties.

Dedicated to Elena, Alexander and Adrián

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KEY TO ABBREVIATIONS

ASOCIAL	Association of Local Agricultural Research Committees
ASOCIALAYO	Association of Local Agricultural Research Committees from the Yojoa Lake
B/C CRSP	Bean Cowpea Collaborative Research Support Program
BGYMV	Bean Golden Yellow Mosaic Virus
CIAL	Local Agricultural Research Committee
CIAT	International Center for Tropical Agriculture
COVA	*Comprobación de Variedades*
CPB	Conventional Plant Breeding
CV	Coefficient of Variation
DICTA	Dirección de Ciencia y Tecnología Agropecuaria
EAP	*Escuela Agrícola Panamericana*, Zamorano
ECAR	*Ensayo Centroamericano de Adaptación y Rendimiento*
FAO	Food and Agriculture Organization
Fi	Filial Generation i; i=1,2,…,6
FIPAH	*Fundación de Investigación Participativa de Honduras*
IRR	Internal Rate of Return
IV	Improved Variety
m.a.s.l.	meters above sea level
NARS	National Agricultural Research Systems
NGO	Non-Governmental Organization
NPV	Net Present Value
PPB	Participatory Plant Breeding
PRR	*Programa de Reconstrucción Rural*
PVS	Participatory Varietal Selection
SIMPAH	Honduran Agricultural Price Information System
SL	Significance level
TLU	Tropical Livestock Units
VIDAC	*Vivero de Adaptación Centroamericana*

CHAPTER 1. INTRODUCTION

1.1. Problem statement

Common beans are Honduras' second most important grain crop (63,220 mt) after maize (467,740 mt) (FAOSTAT, 2006). As in all countries in Central America, the Honduran diet is based mainly on corn and beans, the major source of protein for poor households. While *per capita* bean consumption averages 23 kg, in some rural areas *per capita* consumption is twice that level (Rosas *et al.*, 2003a).

In Honduras, beans are grown mainly by small farmers with less than five hectares, only part of which is planted to beans (Rosas *et al.*, undated-a; Tshering, 2002). Tshering (2002) reported that small farmers account for an estimated 40% of total bean production. These farmers typically grow beans as a rainfall crop on hillsides in marginal areas, apply low levels of purchased inputs, and seldom use a tractor to cultivate their fields (Rosas *et al.*, 2000; Rosas *et al.*, 2003a). Furthermore, biotic (e.g. diseases, pests) and abiotic (e.g. drought, low fertility soils) stresses reduce farmers' yields and threaten their food security since, given their low input production system, they are not able to control for these problems.

During the past decades, small farmers have been offered several options to address biotic and abiotic stresses, including improved bean varieties (IVs) that are resistant to disease and tolerant to drought (Gallardo *et al.*, undated; Rosas *et al.*, 2003a). However, while studies indicate that these varieties are planted by about 41-46% of Honduras' bean farmers (Mather *et al.*, 2003), they have not been adopted by some farmers, especially farmers producing beans in marginal areas. Agricultural scientists have identified participatory plant breeding (PPB) as a strategy for increasing adoption and thereby extending the benefits of IVs to more farmers (Almekinders and Elings, 2001; Atlin *et al.*, 2001; Ceccarelli *et al.*, 2000; Morris and Bellon, 2004; Rosas, 2001; Rosas *et al.*, 2003a, undated-a; Sperling *et al.*, 2001).

1.2. Knowledge gap

Since 1999, Honduran agricultural scientists, in collaboration with NGOs, have implemented a bean PPB project in two regions (Yoro and Yojoa Lake).[1] The establishment of the bean PPB project and the advances made so far are well documented. Rosas (undated-c), Humphries *et al.* (undated) and Gallardo *et al.* (undated) have explained the reasons why PPB was introduced in Honduras and the considerations that were taken into account before implementing the PPB project. Humphries *et al.* (2001) documented the establishment of the project and farmers' perceptions about the project. Several papers have described the procedure followed to release bean varieties using participatory approaches (Gallardo *et al.*, undated; Rosas *et al.*, 2003a, undated-a; Rosas *et al.*, 2003b); and the achievements, benefits to farmers, and challenges faced in implementing the bean PPB project in Honduras (Rosas *et al.*, undated-b; Rosas *et al.*, 2005; Rosas *et al.*, 2006b). Humphries *et al.* (undated) have described the institutions implementing PPB in Honduras, the socioeconomic characteristics of farmers in the country, and the general characteristics of farmers participating in Local Agricultural

[1] At the moment of the study (2006), the project was also being implemented in the Department of El Paraíso, in the southeast region; however, this region was not included in the analysis because they had nothing to evaluate yet (project was in early stages).

Research Committees[2] (CIAL). Finally, Humphries *et al*. (2005) have described how Honduran hillside farmers, Zamorano, and the Foundation for Participatory Research with Honduran Farmers (FIPAH, an NGO) have collaborated to develop improved bean varieties; and identified the need to carry out a cost-benefit analysis of the PPB project in Yorito (department of Yoro).

While the studies described above provide insights regarding the implementation of PPB in Honduras, none have sought to assess the impact of PPB. An economic study is needed to assess the characteristics of PPB and non-PPB farmers, estimate the direct and indirect benefits of the project, evaluate farmers' knowledge about the breeding process, assess women's participation in PPB-related activities, document seed exchange between PPB and non-PPB farmers within the community, and analyze farmers' suggestions for strengthening the project before replicated in other areas of the country.

Thus, this study was conducted to better understand the socioeconomic impact of the PPB project in the Yojoa Lake and Yoro regions where it was implemented and to generate recommendations for guiding the implementation of bean PPB projects in other regions.

1.3. Objectives

The general objective of the study is to empirically assess the socioeconomic impact of the bean participatory plant breeding (PPB) project in the regions of Yojoa Lake and Yoro. Specifically, this study:

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[2] A CIAL is a group of volunteer farmers who are interested in conducting research and experimentation. CIALs belong to and are managed by the rural community, and have links with the formal scientific community (CIAT, 2007).

(1) Provides an overview of the Honduran bean subsector;

(2) Documents (a) the history of PPB, and (b) its similarities and differences with respect to alternative breeding methodologies;

(3) Examines the strengths and weaknesses of the PPB project;

(4) Analyzes the benefits and costs of bean PPB to marginal farmers; and

(5) Generates recommendations for improving the current project and to successfully scale up the PPB methodology in the country, if viable.

1.4. Research questions

This study attempts to answer the following research questions:

(1) What are the characteristics of the Honduran bean subsector and their implications for PPB?

- What farming systems are used in the country?
- What are average farmers’ characteristics?
- What are consumers’ bean preferences?
- What are the bean market channels in the country?
- What implications do these characteristics have for PPB?

(2) What is PPB, how it is being implemented, and what are potential benefits?

- What was the origin of PPB and how similar/different is it compared to conventional plant breeding (CPB) and participatory varietal selection (PVS)?
- What are the potential benefits of the PPB methodology?
- How can these benefits be measured/quantified?

(3) What are the socioeconomic characteristics of farmers who participated/did not participate in the PPB project?

(4) What are the strengths and weaknesses of the bean PPB project?

- What are farmers' perceptions about the project's strengths and weaknesses?
- What are collaborating institutions' (i.e. Zamorano and NGOs) perceptions about the project's strengths and weaknesses?

(5) What are the benefits and costs of bean PPB to Honduran marginal farmers?

- How has the project benefited farmers (e.g. knowledge, varieties released, yields, seed exchange)?
- What are the estimated costs of the PPB project and how do these costs compare to CPB?
- How could PPB be strengthened to increase farmers' income and food security?

(6) Should the bean PPB project be scaled up to cover other regions in the country? If so, how could this be done?

- Are the observed benefits greater than the costs?
- What type of farmers could participate in the project?
- What role should Zamorano, FIPAH and PRR play in scaling up the project?
- How can these collaborators exploit current strengths and avoid observed weaknesses?
- Is PPB self-sufficient in the long run?

1.5. Organization of the document

The document is divided into five chapters. **Chapter 2** describes the methodology used for the research: how the locations were selected; what sampling procedure was used; the data collection method; the conceptual framework; and analysis done.

Chapter 3 provides an overview of the bean subsector in Honduras; and describes PPB, including how it has been implemented and what its potential benefits are. In order to understand PPB, it is helpful to understand other methodologies being implemented with farmers. Therefore, this chapter also describes the CIAL (Local Agricultural Research Committees), conventional plant breeding (CPB), and participatory varietal selection (PVS) methodologies. Finally, a comparison among these three methodologies is presented.

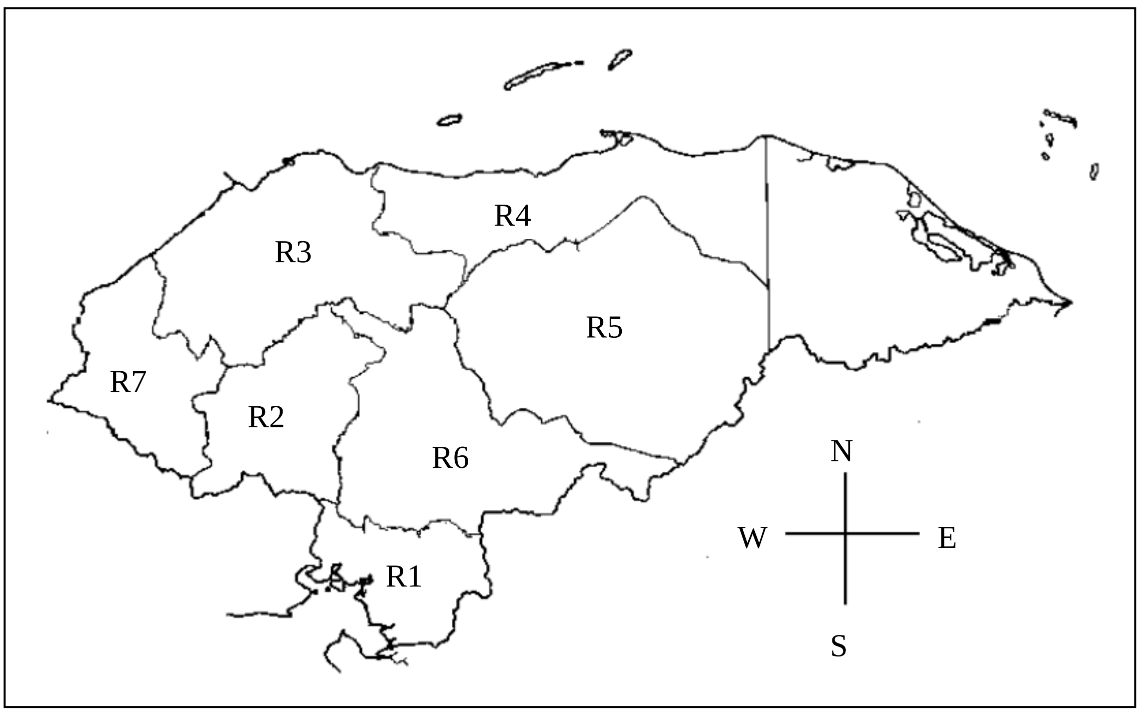
Chapter 4 presents the results. This chapter is divided into four parts. The first part describes farmers' socioeconomic characteristics. The second part depicts the project's strengths and weaknesses; the third part presents the benefits (yield estimation, knowledge, etc) and costs of the project to farmers; and the fourth part analyzes if and how this project could be scaled up.

Chapter 5 presents a summary of the document and identifies policy implications for all stakeholders. In addition, it presents the limitations of the study, and provides some recommendations for future research.

CHAPTER 2. METHODOLOGY

2.1 Sites selection and characterization

Honduras is divided into 18 departments, which are classified into seven agricultural regions (Figure 2.1). From these departments, three departments were selected for evaluation because these were where PPB was being implemented: Yoro, which belongs to the North (R3) and Atlantic Coastal (R4) regions; Comayagua, which belongs to the Center-Occidental (R2) and Center-Oriental (R6) regions; and Santa Bárbara, which belongs to the North (R3) and Occidental (R7) regions (INE, 2005) (Figure 2.2).



Source: Taken from the Encuesta Agropecuaria Básica Noviembre 2005, INE, Honduras.
R= Region

Figure 2.1. Agricultural Regions of the Republic of Honduras.

Source: Modified from the map in the Bean Atlas of the Americas (forthcoming).

Figure 2.2. Departments of Honduras and selected departments. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

Within these departments, a total of nine communities were selected because it was in these communities where PPB was being implemented: five in Yoro; three in Comayagua; and one in Santa Bárbara.[3] Sections 2.1.1 and 2.1.2 provide detailed information about each department and each community. Table 2.1 summarizes the general characteristics of the nine communities evaluated. Additionally, it includes information about the two main towns where farmers usually sell/buy their goods and the distance from each community to these markets. As it can be seen, almost every

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[3] The communities located in the departments of Comayagua and Santa Bárbara were near the Yojoa Lake. Therefore, from now on these communities will be referred to as the communities in the Yojoa Lake region; unless otherwise noted.

Table 2.1. General information about the communities evaluated in the Departments of Yoro, Comayagua, and Santa Bárbara, Honduras, 2006.

Depart-ment	Municipa-lity	Village	Community	CIAL[1] name	Year established	Farmers / CIAL[2]	Altitude (m)	GPS location	Distance to market[3] (km)
Yoro	Yorito	Vallecillos	Mina Honda	Divino Paraíso	1998	11	1,400	15° 3' N; 87° 16' 36" W	6
Yoro	Yorito	Vallecillos	La Patastera	Nueva Superación	1999	4	1,650	n.a.	8
Yoro	Yorito	Pueblo Viejo	Santa Cruz	Santa Cruz	1998	6	1,200	15° 3' N; 87° 13' W	10
Yoro	Yorito	Pueblo Viejo	Pueblo Viejo	Nueva Vida	1999	10	756	15° 4' N; 87° 14' W	11
Yoro	Sulaco	La Albardilla	LR, LL, MG	Chaguitio[4]	1999	12	900	14° 58' N; 87° 17' 60" W	11
Comayagua	San José de Comayagua	Laguna Seca	Laguna Seca	Nueva Visión	1999	16	910	14° 46' 4.62"N; 87° 59' 15.9"W	8
Santa Bárbara	Concepción del Sur	Nueva Esperanza	Nueva Esperanza	Nuevo Amanecer	1999	6	750	14° 48' 28.56"N; 88° 9' 50.4"W	27
Comayagua	Taulabé	El Palmichal	Palmichal	Unidos para Vencer	1995	6	960	14° 45' 3.42"N; 87° 56' 31.14"W	10
Comayagua	Siguatepeque	Buena Vista de Río Bonito	Buena Vista de Río Bonito	Nueva Esperanza	2000	8	1,410	14° 45' 1.14"N; 87° 54' 42.18"W	8
Yoro	Yorito	Yorito	--	--	--	--	766	15° 4' 0"N; 87° 16' 60" W	0
Comayagua	Taulabé	Taulabé	--	--	--	--	561	14° 41' 60"N; 87° 58' 0"W	0

Table 2.1 (cont'd).

Source: INE (2001); Informal group discussions; Falling Rain Genomics (2007); and B/C CRSP survey of PPB project in Honduras 2006.

[1] CIAL = Local Agricultural Research Committee.

[2] Farmers/ CIAL refers to the number of farmers in the CIAL in 2006.

[3] Distance to Market provided by Orlando Mejía, MCA, Honduras 2009, and refers to the distance to Yorito (for communities in the department of Yoro) and to Taulabé (for communities in the departments of Comayagua and Santa Bárbara).

[4] CIAL Chaguitillo includes farmers from three communities: Los Rincones (LR), Lomas Largas (LL), and Monte Galán (MG); all from La Albardilla.

n.a. = not available.

community was very close to their respective main town (except the community of Nueva Esperanza). Communities located in the Yoro Department sell/buy their goods in Yorito, their closest small-sized town. Communities located in the Yojoa Lake region (Departments of Comayagua and Santa Bárbara) sell/buy their goods in Taulabé, their closest small-sized town. Additional information about the communities and towns can be found in Table A.1.

2.1.1 Department of Yoro

This department is located in the North and Atlantic Coastal agricultural regions of the country. It had an estimated (2001) population of 465,414 people (7.1% of total population) (INE, 2008), has a total surface area of 7,939 km^2 (RNP, 2008), and is considered a dry department.

Yoro was first visited in June of 2006. The communities that have participated in the PPB project were located close to the municipality of Yorito and the CIALs of these communities (one per community) belonged to the ASOCIAL Yorito (Association of CIALs of Yorito), which include 35 CIALs. To introduce and pre-test the survey and to obtain general information about the CIALs' work and the PPB project; researchers, NGO officers, officers of the association, and several farmers from different CIALs were invited to a meeting which was held in the facilities of the association, located at FIPAH (*Fundación de Investigación Participativa de Honduras*, an NGO) in Yorito.

From this meeting, it was learned that five communities (each through its own CIAL) have taken part in bean participatory breeding activities.[4] Therefore, these communities were selected for evaluation. Within each community, only some residents

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[4] Four CIALs collaborated together to release one of the varieties: *Macuzalito*

had participated in the project. However, non-participating farmers were allowed to attend meetings and assist with fieldwork whenever they wanted because one of the principles of the CIAL methodology is to invite farmers from the community to participate in their activities.

The selected communities were: Mina Honda, Los Rincones, La Patastera, Santa Cruz, and Pueblo Viejo; all located in the north agricultural region of the country and relatively close to each other (Figure 2.3). Despite this, not every community was car accessible. For example, to get to La Patastera, a one-hour walk (each way) to the top of a mountain was necessary.

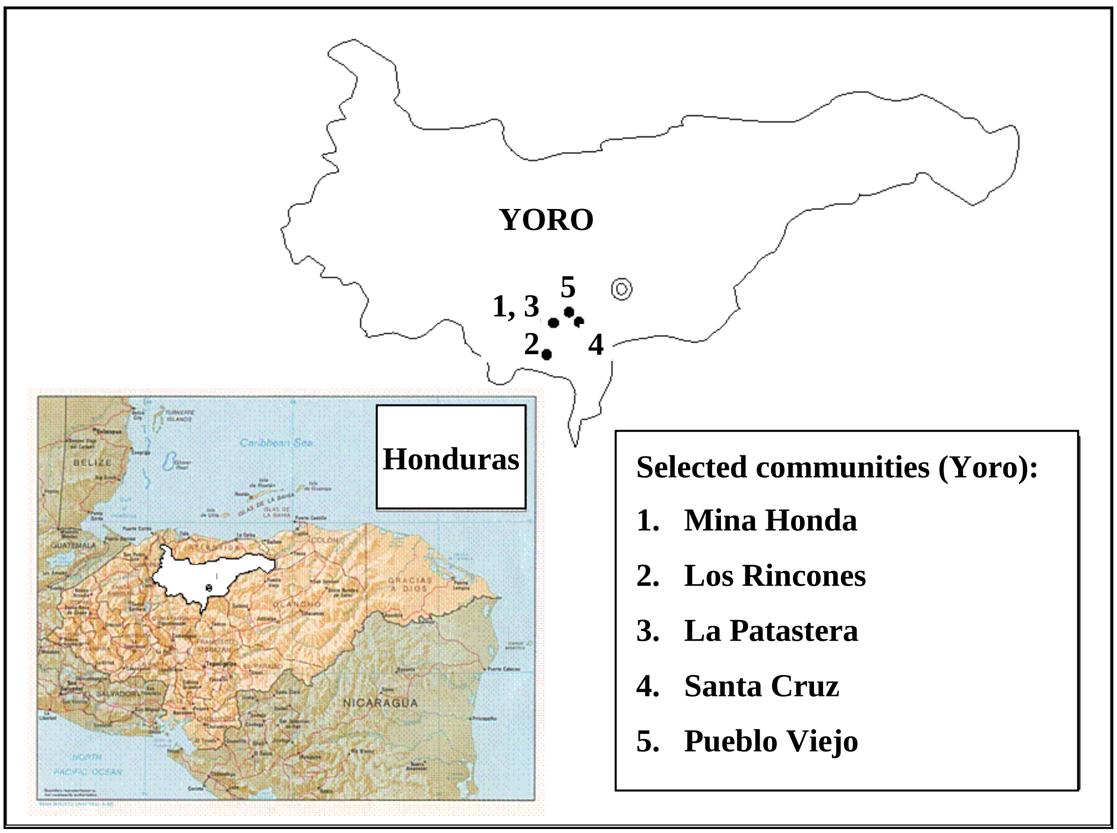

Figure 2.3. Selected communities for participatory breeding evaluation in the department of Yoro, Honduras.

Mina Honda

Mina Honda is part of the village of Vallecillos, which belongs to the municipality of Yorito. It is 1,400 m.a.s.l. The community is car accessible, but the roads are in bad shape. Cereals are the main crops cultivated in the community. In this community, the CIAL was created in 1998. In addition to a small beans germplasm bank (containing both landraces and PPB lines), the CIAL had a small nursery for trees, which it used for a reforestation project.

At the time of the study, 11 farmers were members of the CIAL. These farmers reported that the main activities of the CIAL were related to staple crops (trials and farming techniques; mostly beans and corn), natural resources management and reforestation, soil conservation, seed selection and storage, and the germplasm bank.

Los Rincones

Los Rincones is part of the village of La Albardilla, which belongs to the municipality of Sulaco. It is 900 m.a.s.l. The community, which has good roads, is accessible by car. In this community, the CIAL was created in 1999. At the time of the study, 12 farmers were members of the CIAL. They reported that the main activities of the CIAL were related to staple crops (trials and farming techniques), natural resources management and reforestation, soil conservation, seed selection and storage, production of compost, and community development.

La Patastera

La Patastera is part of the village of Vallecillos, which belongs to the municipality of Yorito. It is 1,650 m.a.s.l. The community is not car accessible. To reach the community, it is necessary to walk approximately one hour to the top of the mountain.

This community has a small school. In this community, the CIAL was created in 1999**.** At the time of the study, four farmers were members of the CIAL. These farmers reported that the main activities of the CIAL were related to staple crops (farming techniques) and potatoes (trials and production), soil conservation, vegetable and coffee production, compost production, and community development.

Santa Cruz

Santa Cruz is part of the village of Pueblo Viejo, which belongs to the municipality of Yorito. It is 1,200 m.a.s.l. The community is car accessible with good roads. In addition to cereals, coffee is produced in the area. In this community, the CIAL was created in 1998. At the moment of the study, six farmers were members of the CIAL. These farmers reported that the main activities of the CIAL were related to staple crops (trials and farming techniques; mainly corn), soil conservation, seed selection and storage, compost production, and community development.

Pueblo Viejo

Pueblo Viejo is part of the village of Pueblo Viejo, which belongs to the municipality of Yorito. It is 756 m.a.s.l. The community is car accessible with good roads. In addition to cereals, coffee production is common in the area. In this community, the CIAL was created in 1999**.** At the moment of the study, 10 farmers were members of the CIAL (all women). These farmers reported that the main activities of the CIAL were related to staple crops (trials, new farming techniques, and production), vegetable and coffee production, seed selection and storage, and home activities for income generation.

2.1.2 Yojoa Lake region: Departments of Comayagua and Santa Bárbara

The department of Comayagua is located in the Center-Occidental and Center-Oriental agricultural regions of the country, while the department of Santa Bárbara is located in the North and Occidental regions. They have an estimated (2001) population of 352,881 and 342,054 people (approximately 5.4% and 5.2% of total population), respectively (INE, 2008).

Comayagua has a total surface area of 5,196 km^2 and a hot and wet climate. Coffee, sugarcane, and corn are among the main crops cultivated in this department. Additionally, cattle, horse and hog production are common activities (RNP, 2008).

Santa Bárbara, which has a total surface area of 5,115 km^2, has several rivers. Its economy is based on agriculture and livestock. The main farming activities are coffee, sugarcane, cereals, plantains, tobacco, and cattle and horse production. Additionally, its population is widely dispersed in small villages (RNP, 2008).

A key informant reported that the communities that had participated in the PPB project were located around Yojoa Lake and that the CIALs of these communities (one per community) were affiliated with the ASOCIALAYO (Association of CIALs of Yojoa Lake), which included 12 CIALs. To introduce the survey and to obtain general information about the CIALs' work and the PPB project; researchers, NGO officers, officers of the association and several farmers from different CIALs were invited to a meeting which was held at the facilities of ASOCIALAYO, which are located at PRR (*Programa de Reconstrucción Rural*, an NGO), ten minute drive from Yojoa Lake.

From this meeting, it was learned that four communities had taken part in PPB. Therefore, these communities were selected for evaluation. As in Yoro, only some residents had participated in PPB. However, non-participating farmers are allowed to attend meetings and assist with field work whenever they want.

The selected communities were: Buena Vista, Palmichal, and Laguna Seca, in the Center-Occidental agricultural region of the department of Comayagua; and Nueva Esperanza in the north agricultural region of Santa Bárbara (Figure 2.4).

<u>*Laguna Seca*</u>

Laguna Seca is part of the village of Laguna Seca, which belongs to the municipality of San José de Comayagua. It is 910 m.a.s.l. The community is car accessible with good roads. Coffee, beans, tropical fruits, and corn are the major crops in

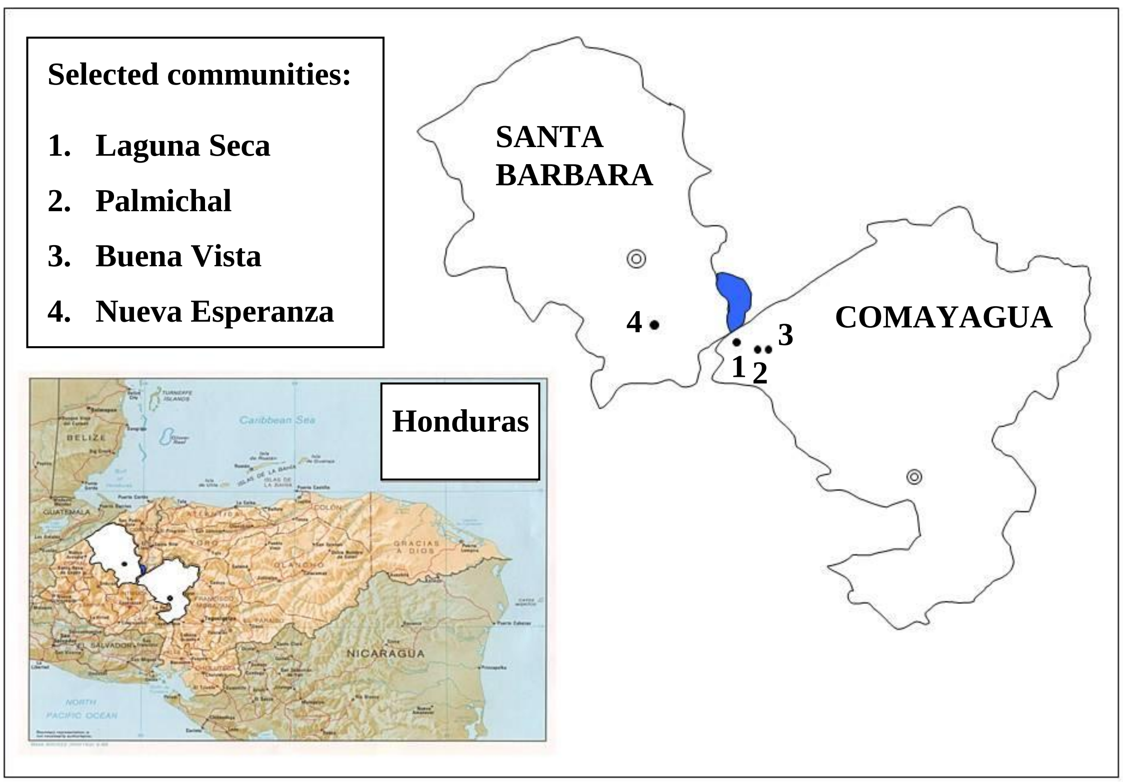

Figure 2.4. Selected communities for participatory breeding evaluation in the departments of Comayagua and Santa Bárbara, Honduras.

the area. In this community, the CIAL was created in 1999. At the time of the study, 16 farmers were members of the CIAL. These farmers reported that the main activities of the CIAL were related to staple crops (trials and farming techniques; mostly beans, corn, and soybeans), natural resources management and reforestation, soil conservation, vegetable, coffee and hog production (they have their own pig house), compost production, and community development. According to a key informant, farmers who were not members of the CIAL thought that farmers in the CIAL were not sharing money given by the government to the community, resulting in a rivalry with CIAL members. This was clearly due to a lack of communication between the CIAL and the rest of the community, as this was not true.

Palmichal

Palmichal is part of the village of El Palmichal, which belongs to the municipality of Taulabé. It is 960 m.a.s.l. The community is car accessible with very good roads.

In this community, the CIAL was created in 1995**.** At the time of the study, six farmers were members of the CIAL. These farmers reported that the main activities of the CIAL were related to staple crops (trials and farming techniques; mostly beans and corn), natural resources management and reforestation, soil conservation, coffee production, and compost production.

Buena Vista

Buena Vista is part of the village of San José de la Cuesta, which belongs to the municipality of Siguatepeque. It is 1,410 m.a.s.l. The community is car accessible with very good roads and close to Palmichal. Because this is almost entirely a coffee grower community, beans (mostly black) are produced mainly for household consumption. In addition, available varieties do not perform very well to the environment because it is very humid, which increases the incidence of diseases (especially web blight and rust).

In this community, the CIAL was created in 2000**.** At the time of the study, eight farmers were members of the CIAL. These farmers reported that the main activities of the CIAL were related to staple crops (trials and farming techniques; mostly beans and corn), soil conservation, coffee production, and compost production.

Nueva Esperanza

Nueva Esperanza is part of the village of Nueva Esperanza, which belongs to the municipality of Concepción del Sur. It is 750 m.a.s.l. The community is car accessible with good roads. Rice, corn and soybeans are the major crops produced. This region has many institutions that work with farmers, which increases competition among institutions and reduces the time farmers have available to participate in new projects. Therefore, some farmers were reluctant to participate in projects unless they were given some kind of compensation (usually money).

In this community, the CIAL was created in 1999. At the time of the study, six farmers were members of the CIAL. Additionally, a newly established 100% female CIAL was working on participatory breeding, but these farmers were not surveyed because they had relatively little experience with PPB. Interviewed farmers reported that the main activities of the CIAL were related to staple crops (trials and farming techniques; mostly beans and corn), and coffee and cassava production.

2.2 Sampling procedure

During the informal group discussions conducted prior to implementing the survey, the communities that had worked with PPB were identified and information about the total number of farmers who have participated in the project in each community was collected. Given the small number of communities that had participated in PPB, all were included in the analysis. Within each community, the number of participant farmers (i.e. CIAL members) was very small. Therefore, to ensure enough participant farmers in the sample, 50-100% of participant farmers were randomly selected within each CIAL.[5] In Yoro, 60% (N= 26) of the farmers involved in the project were surveyed, verses 89% (N= 32) in the Yojoa Lake region (Table 2.2). In each location, an equivalent number of non-participant farmers were randomly selected (see Table A.1 for more details).

Initially, a total of 120 surveys were proposed for the analysis. However, only 115 surveys were conducted because some farmers were not willing to participate in the study. From these, several surveys were excluded from the study because farmers were not bean producers or agriculture was not their main activity, recently moved to the community, or their answers were inconsistent (Table 2.3).

[5] The difference in the percentage of PPB farmers was given by the size of each CIAL. If the CIAL only had 4 members, all were interviewed; however, if the CIAL had 16 members, not all members were interviewed.

Table 2.2. Share (%) of CIAL members interviewed per region and community, Honduras, 2006.

Region / Community	No. CIAL members: Total	Interviewed	Share of total CIAL members (%)
Yoro	43	26	60
Mina Honda	11	6	55
La Patastera	4	3	75
Santa Cruz	6	5	83
Pueblo Viejo	10	5	50
Los Rincones	12	7	58
Yojoa Lake	36	32	89
Laguna Seca	16	12	75
Nueva Esperanza	6	6	100
Palmichal	6	6	100
Buena Vista	8	8	100
Total	78	58	74

Source: B/C CRSP Survey of PPB project in Honduras, 2006; Informal group discussions.

Table 2.3. Proposed, realized and valid surveys per PPB participation and region, Honduras, 2006.

	PPB-participant?		Region (all farmers)*		
Number of	No	Yes	Yoro	Yojoa Lake	Total
Proposed	60	60	60	60	120
Realized	57	58	57	58	115
Valid surveys	53	55	54	54	108

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

* Includes both PPB and non-PPB farmers.

2.3 Data

The study used several data collection methods, including informal group discussions, primary data collection through structured household surveys, and personal interviews with key informants. In addition, secondary data were collected. First, informal group discussions were conducted to gather information regarding the CIAL work and the bean PPB project. At these meetings, information regarding which communities had worked with PPB was collected. Additionally, general information about the history of the project's implementation, the CIAL priorities during the PPB process, and PPB's benefits, weaknesses, and challenges were collected. The survey was pre-tested and questions were revised in order to make them clearer to farmers.

Second, the farmers were surveyed face-to-face. Each interview took about one hour to complete. After finishing the interview, a handbook of bean production was given to farmers as compensation for their time. Most of the farmers knew how to read or had relatives who could read. In cases where a sampled farmer declined to participate in the study, a replacement was drawn from the same community. Approximately ten non-PPB participants declined to respond to the survey; five of whom were replaced and the other five were not. The data were entered in the SPSS® Statistical Program and then analyzed using the STATA® Statistical Program. The household survey was conducted from July 2006 to August 2006.

Third, a semi-structured interview was conducted with key informants to gather additional general information regarding conventional breeding, the bean PPB project, and strengths and weaknesses of both conventional and participatory plant breeding. Key informants included: (1) the Principal Bean Breeder of Zamorano (*Escuela Agrícola*

Panamericana, a private university); (2) the Bean Breeder of the Honduran National Bean Program at DICTA (*Dirección de Ciencia y Tecnología Agropecuaria*); (3) staff from FIPAH, the NGO directly collaborating with participating farmers in the department of Yoro; and (4) staff from PRR, the NGO directly collaborating with participating farmers in the Yojoa Lake region.

Finally, secondary data on the Honduran bean subsector (production and price data), and bean trials data were collected from the Food and Agriculture Organization (FAO) Statistical Database, Michigan State University's (MSU) Department of Agricultural, Food, and Resource Economics (AFRE) *Common Bean Atlas of the Americas*; *Banco Central de Honduras* (BCH); Zamorano's *Proyecto de Investigaciones en Frijol* (PIF) Database (available on site only); and a couple of CIAL's Database (available on site only).

2.4 Conceptual framework

Ex post evaluation of agricultural research can be done using parametric, non-parametric, or index-number approaches (Alston *et al*., 1998). To evaluate the effect of PPB, both descriptive and econometric approaches were used. Most of the information was evaluated by using descriptive statistics. Additionally, a single-equation linear regression model was estimated to evaluate factors associated with differences in farmers' yields. This approach was used to evaluate PPB's direct impact on farmers because PPB's main objective is to increase the yields of local varieties, while preserving their good traits (e.g. market value).

Conceptually, yields at time t can be estimated by:

$$Q_t = f\left(X_t, K_t, U_t, F_t, Z_t\right)$$

where yields (Q_t) depend on production-related variables, X_t, project-related characteristics, K_t, socioeconomic characteristics, U_t, financial-related variables, F_t, and several quasi-fixed factors, Z_t (modified from Alston *et al*., 1998, page 104).

In applied econometric work, it is common to replace variables in the theoretical model with more readily available variables that are intended as proxies for the true variables (Alston *et al*., 1998). In the estimated model for yields, several proxy variables were used to replace variables for which data were not available or not collected. As mentioned by Alston *et al*. (1998), two problems may arise from these adjustments: estimates may be biased and inefficient because of the imperfect correlation between the proxies and the "true" variables, and interpretation of proxies may be problematic, if the units of the proxies differ from those of the corresponding "true" variables. Despite these constraints, most practitioners seem reconciled to accepting whatever biases are involved and expect that they are not too important (Alston *et al*., 1998).

The survey data were analyzed using the STATA® Statistical Program. As mentioned above, descriptive statistic was used for most of the data analysis and the linear regression analysis was carried out to evaluate factors associated with differences in farmers' yields. The results of the analysis were used to assess if and how the PPB project should be scaled up and the role each stakeholder could play to strengthen the PPB project in Honduras.

2.5 Chapter summary

The Central American country of Honduras is divided in 18 departments. From these, the departments of Yoro, Comayagua, and Santa Bárbara were selected for the study because the participatory breeding project was first implemented in these departments. Yoro is the most populated and biggest department, compared to Comayagua and Santa Bárbara. Within these departments, five communities were selected in Yoro, three in Comayagua, and one in Santa Bárbara. The last four communities were located in the area surrounding Yojoa Lake. In each region (i.e. Yoro and Yojoa Lake), the selected communities were relatively close to each other. However, they were located in elevations that ranged from 676 to 1,650 m.a.s.l. in Yoro and from 750 to 1,410 m.a.s.l. in the Yojoa Lake region.

In Yoro, 60% (N= 26) of the farmers involved in the project were surveyed, verses 91% (N= 32) in the Yojoa Lake region. These farmers were randomly selected. In each location, an equivalent number of non-participant farmers were randomly selected and surveyed (total sample: N=58 PPB participants and N=57 non-PPB participants). The study used several data collection methods, including informal group discussions, primary data collection through structured household surveys, and personal interviews with key informants. In addition, secondary data were collected. The survey data were analyzed using descriptive statistic and a linear regression analysis was carried out to identify factors associated with yields.

To evaluate the effect of PPB, both descriptive and econometric approaches were used. However, most of the information was evaluated using descriptive statistics. Economic theory suggest that farmers will maximize production (yields) subject to a set of constraints, which include production- and project-related constraints, quasi-fixed factors, and socioeconomic characteristics of the farmers. A single-equation linear regression model was estimated to evaluate the socio-economic factors associated with differences in yields.

CHAPTER 3. LITERATURE REVIEW

3.1 Honduran bean subsector

The Republic of Honduras is the second largest Central American country (after Nicaragua) with 43,278 sq. mi.[6] In terms of land use, FAO classifies 26% of the country's land area as agricultural, of which 36% is classified as arable (FAOSTAT, 2008).

Rainfall varies, depending on the region. In the north coast, it rains throughout the year; while in the rest of the country, the rainfall is heaviest between May and November. Annual precipitation is highest near Yojoa Lake in the northwest.[7] In contrast, the department of Yoro is one of the driest parts of the country, with an average of less than 500 mm per production season.[8]

3.1.1 Honduras' socioeconomic characteristics

Honduras has a total population of 7.36 million (2006), which is increasing at an annual rate of 2.3%. Of the total population, 51% lives in rural areas. Tegucigalpa and San Pedro Sula (the two main cities in the country) account for approximately 41% of the country's total population (BCH, 2006). The World Bank (2008) reports that 39% of the population is less than 14 years of age.

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[6] Information from: http://www.state.gov/r/pa/ei/bgn/1922.htm.

[7] Information from the World of Information Business Intelligence Report at: http://www.lexisnexis.com.proxy2.cl.msu.edu:2047/us/lnacademic/search/homesubmitForm.do.

[8] Source: Bean Atlas of the Americas (forthcoming web page created by the Department of Agricultural, Food, and Resource Economics, Michigan State University).

Honduras' per capita income averages $1,200 (2006), the second lowest among Central American countries. As in most of the Central American countries, poverty is widespread. While 50% of the population lives below the poverty line, 70% of the rural population and 30% of the urban population live below the poverty line (World Bank, 2008). Comparing these indicators to the data reported by Tshering (2002) indicates that at the national level, the share of the population below the poverty line has decreased (from 53% to 50%). However, the percentage of the rural population below the poverty line has increased (from 51% to 70%), while the percentage of urban population below the poverty line has decreased (from 57% to 30%).

3.1.2 Bean farming systems and average farmers' characteristics

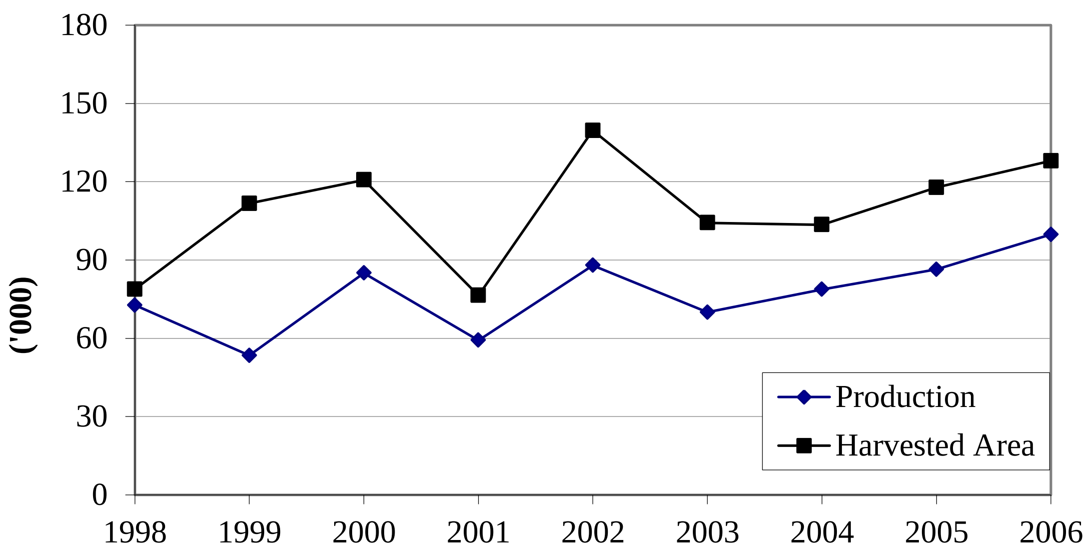
In Honduras, the agricultural year spans the period from April 1st of the year of reference to March 31st of the following year. The growing season is divided into two periods--the *Primera* (May-August) and the *Postrera* (September-December) season (INE, 2005). In the 2005 agricultural year, farmers planted 76,385 ha (hectares, 1 ha = 10,000 m^2) of beans with a total production of 63,222 MT (1 MT = 1,000 kg) and yields averaged 828 kg/ha (FAOSTAT, 2006; INE, 2006).

As described by Mather *et al*. (2003), maize, the principal crop in the *Primera,* is either intercropped with beans or monocropped. If intercropped, beans are planted mainly to multiply seed for farmers' *Postrera* planting. In the *Postrera*, beans are mainly monocropped. This suggests that the two main farming systems used by Honduran farmers to produce beans are intercropping (usually with maize) and monocropping.

In recent years (1998-2006), the harvested area has varied greatly from year-to-year, while production has remained relatively stable over the period, averaging 77,013 MT (Figure 3.1).

In Honduras, beans are grown mainly by small farmers with less than five hectares of land--only part of which they plant to beans (Rosas *et al.*, undated-a; Tshering, 2002). Tshering (2002) reported small farmers account for an estimated 40% of total bean production.

Small farmers typically grow beans as a rainfed crop in marginal areas and apply low levels of purchased inputs (Rosas *et al.*, 2000; Rosas *et al.*, 2003a). While one-third of the bean area is planted in fields with less than 5% slope, 55% of the bean area is planted in hillsides on fields with more than 10% slope (Table 3.1).



Source: Generated from FAOSTAT data, 2010

Figure 3.1. Honduras common bean production ('000 MT) and harvested area ('000 ha). 1998-2006.

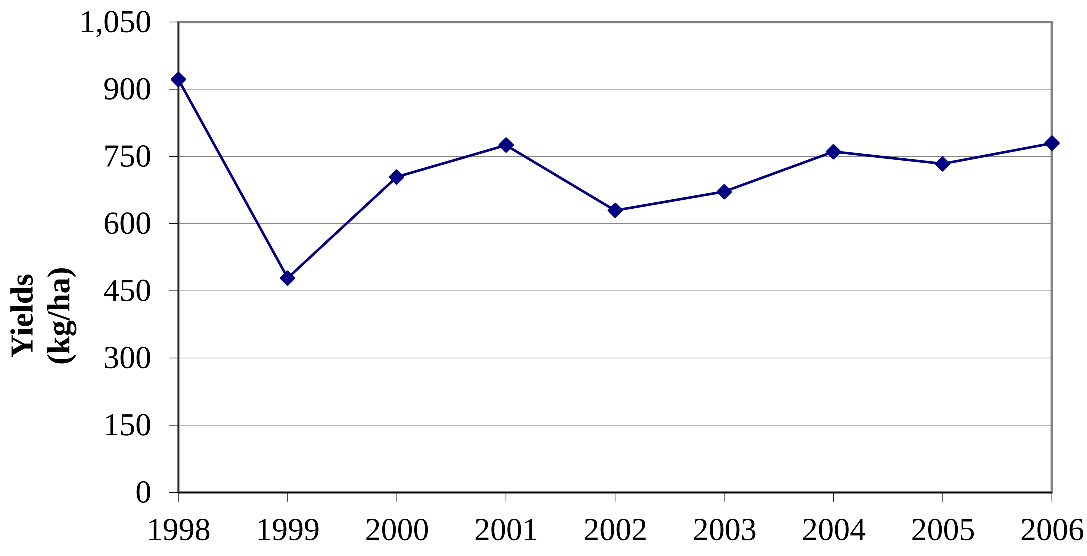
Table 3.1. Honduras common bean planted area by elevation.

Slope (%)	**Hectares**	**Share (%) of total**
0-5	35,121	35.7
5-10	8,698	8.8
10-15	8,424	8.6
15-30	25,974	26.4
>30	20,077	20.4
Total	98,294	100

Source: Bean Atlas of the Americas (web page under construction, MSU); which used data from the IV National Agricultural Census, 1993.

Small-scale bean farmers typically store their harvest for self-consumption, save seed for planting in the following cropping season, and sell their surplus production. Rosas *et al.* (2000) reported that small farmers sell 55% of their production--usually to intermediaries, who come to the farm since small farmers also lack access to transportation, rural roads are in bad physical conditions, and their farms are located far from the main cities.

Over the period 1998-2006, bean yields averaged 717 kg/ha with a coefficient of variation of 17%. However, yields varied considerably from year-to-year, ranging from 479 kg/ha (1999) to 922 kg/ha (1998, before hurricane Mitch). Since 2000, yields have been relatively stable, ranging from 630 kg/ha to 775 kg/ha (Figure 3.2). Both biotic and abiotic stresses greatly affected yields. For example, low yields in 1999 were due to damage caused by hurricane Mitch, which struck the country in late October 1998.



Source: Generated from FAOSTAT data, 2010

Figure 3.2. Honduras common bean yields (kg/ha). 1998-2006.

3.1.3 Consumer preferences for beans

While both black (5% of production) and small red (95% of production) beans are grown in Honduras, most consumers prefer small light-red beans. As noted by Tshering (2002) and Mather *et al.* (2003), consumers' preferences for beans depend on color, size, shape, freshness, cooking time and taste.

3.1.4 Bean market channels

The bean marketing channels for Central American countries have been described by several authors (Martel-Lagos, 1995; Martinez, 2003; Mendoza, 2008; Tshering, 2002; Zamora, 2005). As these authors noted, the marketing channels are similar among Central American countries. The principal agents in the supply chain are farmers/producers, local retail shops (*"pulperias"*), regional traders (middlemen or *coyotes*), producer's associations, wholesalers, non-traditional intermediaries, international traders (especially Salvadorians), the Honduran Institute for Agricultural Marketing (IHMA), BANASUPRO, bean packers, bean processors, distributors, and urban retailers.

Farmers usually store part of their production and sell their surplus to either local traders or regional traders. If farmers belong to an association, they sell their surplus (or at least part of it) to the farmer's association. Local traders are small stores (*pulperias*) located in each community and/or nearby communities, while regional traders (*coyotes*) are usually middlemen from the community or nearby city who operate over a large geographical area than do local traders. Frequently, regional traders are associated with wholesalers.

As described by Martel-Lagos (1995), Martinez (2003), Mendoza (2008), and Zamora (2005), wholesalers buy beans from farmers, some local traders, and regional traders; and then sell these to distributors, processors, packers, and consumers. Martinez (2003) noted that non-traditional intermediaries, who represent supermarkets and other retail stores, procure beans directly from farmers, associations or other intermediaries on their behalf.

The Honduran Institute for Agricultural Marketing (IHMA) was supposed to improve the production and marketing efficiency of basic grains. However, its role as a handler of grains has been significantly reduced and its impact on the market has been minimal (Martel-Lagos, 1995). BANASUPRO, a food retailing parastatal, is authorized to contract beans with producer groups or import beans if necessary and distribute these procured beans through its national chain of food stores (Martel-Lagos, 1995; Tshering, 2002).

Bean packers and bean processors usually add value to beans by cleaning them before selling them to retailers or exporting them.

3.1.5 Implications for PPB

The Honduran bean subsector characteristics described above suggest that:

1) PPB could be a useful methodology for improving rural population's (particularly small farmers) food security through the development of new bean varieties with higher yields because approximately 50% of the country's population live in rural areas and 70% of them live below the poverty line. Additionally, their diet is based on beans as one of the major sources of protein.

2) As it has been stated for several authors, PPB could be oriented to develop bean varieties adapted to the marginal areas where small Honduran farmers crop their bean varieties. Because these farmers account for 40% of the country's production, mostly grow their beans on hillsides, and apply low levels of purchased inputs, developing bean varieties adapted to these marginal environments could increase the country's production, farmers' income, and food security.

3) While most consumers prefer light-red bean varieties, PPB could also be oriented to develop black varieties either for the export market or for the northwest region of the country. However, its impact would likely be greater when applied to red varieties because 95% of consumers prefer this market class.

4) Given that farmers sell their surplus mostly to middlemen, PPB projects could help farmers find alternative ways to commercialize their surpluses. Because producer

associations are also important players in the marketing channels, farmers could sell their surplus through their associations (CIAL or CIAL associations), obtaining marketing margins (if any) usually obtained by the middlemen. This can be possible because in Honduras, PPB has been implemented with farmers organized in groups (i.e. CIAL). Therefore, once the varieties have been developed, these could be marketed through these associations/groups. However, for this to be achieved, farmers need to be efficient (at least as efficient as the middlemen) in marketing beans to the next player in the supply channel, rather than to the middlemen.

3.2 The evolution of PPB

In order to better understand the PPB methodology, it is useful to explain other methodologies being implemented by farmers and factors that led to PPB as it is implemented today, including the CIAL methodology, conventional plant breeding, and participatory varietal selection.

3.2.1 Local Agricultural Research Committees (CIAL)

3.2.1.1 CIAL history

According to Ashby et al. (2000), the CIAL concept (village-based farmer research group) was developed by scientists at the International Center for Tropical Agriculture (CIAT). In 1982, while working in a collaborative project between CIAT and the International Fertilizer Development Center (IFDC) which sought to persuade farmers to adopt fertilization recommendations, Ashby realized that farmers were reluctant to adopt these recommendations because they considered them too risky in their growing environment.

After the project ended, the Kellogg Foundation provided funds to implement a three-year (1987-1990) participatory research project. The goal of the project was to both train researchers how to carry out participatory research and to further develop the principles, processes, and tools for such an approach. The project, which was named "*Investigación Participativa con Agricultores*" (Participatory Research with Farmers, IPRA), was implemented by a team of social scientists and agronomists. Results of the project were clear: involving farmers early in the research process has the potential to avoid developing technologies that are not adopted by farmers. Also, by providing a researcher to advise the farmers, they increased their use of inputs. Additionally, farmers selected some options that otherwise would have been rejected by researchers.

Despite this success, farmers wondered what would happen once the project ended and CIAT left the community. In talks to address this concern, CIAT researchers found that farmers were willing to form small groups and continue with the research on their own, sharing results with the community. However, farmers recognized that they needed assistance from an agronomist and that a source of funds would be required to support this initiative.

3.2.1.2 General characteristics

A CIAL is a farmer-run research service that investigates production problems within their communities and solves them. The members of the CIAL are chosen by community members because of their interest in conducting research and willingness to serve (CIAT, 2007). This local research service belongs to and is managed by the rural community, serves as a bridge between research-farmers and formal scientists, and increases the community's capacity to access new techniques, information and research products that can be used at the local level (CIAT, 2007).

The CIAL conducts research on priority topics identified by local farmers through a diagnosis process. After each experiment, the CIAL provides feedback to the community. Additionally, each CIAL has a small fund to support its work and is assisted by an external facilitator until it reaches maturity (Ashby *et al.*, 2000). According to Ashby, one-half of the CIALs in Latin America are supported by non-government organizations (NGO), one-quarter by government organizations and the rest by consortia (i.e. two or more cooperating organizations) (Ashby *et al.*, 2000; CIAT, 2007).

3.2.1.3 CIAL methodology

The CIAL methodology is based on eight steps, as follows: motivation, election, diagnosis, planning, experimentation, evaluation, analysis, and feedback to the community (Ashby *et al.*, 2000; Humphries *et al.*, 2005; CIAT, 2007).

During the motivation stage, the external facilitator presents the CIAL initiative to farmers in the community. Then, the community decides whether or not to establish a CIAL. Once the community decides to establish a CIAL, they choose a committee of four officers (coordinator, secretary, treasurer and extension agent) during the election stage. After the committee is established, farmers in the community meet to analyze current problems and decide which topics to include in the research agenda; this is the diagnosis stage.

During the planning stage, the details about the experiments are finalized and additional information required to carry out the research is obtained. Then, during the experimentation stage, the experiments take the form of controlled trials through which new varieties or practices are compared with local ones and data from the trials are collected. This information is then evaluated by farmers and the facilitator (extension agent) and together they prepare the results for presentation to the community.

During the analysis stage, CIAL members use the information to answer simple questions like “What have we learned?” or “Why did the techniques/varieties tested fail?” Finally, the CIAL members present the results (experiment methods, expenses, etc) to community members, in order to spread the knowledge gained.

3.2.1.4 Potential benefits and costs

Ashby *et al*. (2000) and CIAT (2007) point out that the research conducted by the CIALs benefits the whole community, not just the participant farmers. This study takes this into consideration by including non-CIAL farmers in the sample. However, it does not include non-CIAL communities (which would give a “true” control group). While the CIAL benefits vary, depending on the maturity of the CIAL and topic of research, the benefits may include: increased local capacity in formal research methods; improved local planning, management and organizational skills; higher crop yields; local experimentation; higher biodiversity in cropping systems; improved access to credit, greater availability of improved seed; and increased food security.

As one might expect, the cost (to investors) of establishing a CIAL is higher during the first years, but decreases as the CIAL matures. This is because during the first years, it is necessary to invest in training. In subsequent years, the costs depend on the number of visits and the number of CIALs supervised by the facilitator. On average, the estimated cost per CIAL is $670 for the first year but it averages $325 per year for years one to six (Ashby *et al.*, 2000; CIAT, 2007). In year six, the cost is as little as $100 per year (Ashby *et al.*, 2000); therefore, after year six, the cost may remain as low as $100 per CIAL since no major investments are required.

3.2.1.5 CIALs in Latin America and Honduras

Currently, the CIAL methodology has been implemented in eight Latin American countries: Colombia, Honduras, Ecuador, Bolivia, Brazil, Nicaragua, El Salvador, and Venezuela. The first two countries to implement the methodology (Colombia and Honduras) have formed the highest number of CIALs (Ashby *et al.*, 2000). Additionally, CIAT (2007) reports that more than 250 CIALs have been formed in Latin America.

In Honduras, the first two CIALs were established in 1993, as part of a pilot project in the northern region (Humphries *et al.*, 2005). At the time of this study (2006), 98 CIALs conducted research throughout the country (CIAT, 2007), involving more than 930 farmer-researchers supported by Zamorano (*Escuela Agrícola Panamericana*, a private university) and two NGOs --the *Fundación de Investigación Participativa de Honduras* (FIPAH) and the *Programa de Reconstrucción Rural* (PRR) (Humphries *et al.*, 2005).

3.2.2 Conventional Plant Breeding (CPB)

3.2.2.1 General characteristics

Fehr (1939) describes plant breeding (PB) as the art and science of the genetic improvement of plants. When humans first selected one plant over another, PB became a tool in agriculture. Gepts (1988) provides an extensive review of archaeological evidence about the domestication of common beans (*Phaseolus vulgaris*) and other bean species. Common beans were domesticated between 2,300 B.P. to 8,000 B.P. (Before Present time) in different regions of the Americas and the major evolutionary changes under domestication are gigantism (small vs. large seed size), seed dispersal mechanisms (explosive vs. non-explosive dehiscent pods), changed growth form (climbing vs. bush types),[9] changed life-form (perennial vs. annual),[10] and loss of seed dormancy, among other physiological changes (Gepts, 1988).

Initially, the only tool available for crop improvement was plant observation – farmers selected plants with preferred characteristics and replanted the seed of these plants. Today, although breeders still use phenotype as a selection tool, additional tools (i.e. research centers, molecular markers, scientific information) have been added to the breeding toolkit to help scientist implement an effective program of genetic improvement (Fehr, 1939). The use of these tools has contributed to the rapid development of new varieties using ‘conventional’ plant breeding (CPB) techniques.

Scientist-led CPB is based on a centralized global research model: breeders (scientists) collect germplasm from different sources, evaluate it under controlled experimental conditions, cross superior materials, and distribute the progeny, following selection, to collaborators in national agricultural research systems (NARS) for field testing (Morris and Bellon, 2004). Finally, breeders select ‘stable’ (genetically homogeneous) materials to test under farmers’ field conditions and officially (formally) release the best performing lines from these trials as improved varieties (IVs) (Rosas, 2006a).

3.2.2.2 Bean CPB strengths and weaknesses

Strengths

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[9] Although many domesticated beans are climbing beans.
[10] However, most wild common beans are also annual.

The strengths of CPB methods include: 1) the elimination of redundant activities in the breeding process, because it operates at a regional or global level; 2) the extensive exchange of germplasm, because breeders interact with each other and exchange germplasm with scientists in national and private programs around the world; 3) multi-location testing in collaboration with national programs; and 4) exploitation of technology spillovers (Morris and Bellon, 2004).

During the 1990s, bean breeding programs in Latin America focused on developing varieties with a wider genetic base, which were adapted to a broad range of environments (Rosas *et al.*, 2003a). Rosas et al. (2003a) noted that most of the varieties released to date have these characteristics and, additionally, are resistant to diseases and have a higher yields potential, compared to landraces. In Central America and the Caribbean, agricultural research centers have developed bean varieties that are resistant to diseases [BGYMV (Bean Golden Yellow Mosaic Virus), BCMNV (Bean Common Mosaic Necrotic Virus), rust, web blight, CBB (Common Bacterial Blight)], and with tolerance to high temperatures (Beaver *et al.*, 2003) --the main constraints to high yields.

Since 1967, NARS, in collaboration with the International Center for Tropical Agriculture (CIAT), have released 584 bean IVs worldwide. Of this total, almost 55% have been released in Latin America and the Caribbean. While Brazil has released the greatest number of varieties, Honduras is in tenth place with 15 bean varieties released since 1980 (CIAT, 2001b). Beaver *et al.* (2003) reported that since 1981, 18 bean IVs have been released by national programs in Latin America and the Caribbean in collaboration with the Bean/Cowpea Collaborative Research Support Project (B/C CRSP). These authors observed that varietal development requires a network of research programs because no single research institution can address for all of the factors that constrain bean production.

Weaknesses

Although CPB has been very effective in producing input-responsive, broadly-adapted varieties of crops (Atlin *et al.*, 2001), some of its weaknesses include: 1) low adoption of CPB varieties in marginal areas; 2) exclusion of marginal farmers' needs when defining breeding priorities; 3) inefficient testing procedures and varietal release processes; and 4) loss of biodiversity.

While studies indicate that improved bean varieties are planted by 41-46% of Honduras' bean farmers (Mather *et al.*, 2003), they have not been adopted by some farmers --mainly because of inefficient seed dissemination channels (Rosas *et al.*, 2003a), farmers' lack of access to good quality seed, their lower market price compared to landraces[11] (Mather *et al.*, 2003; Rosas *et al.*, 2003a), and their low adaptability to production systems used by small farmers (Morris and Bellon, 2004; Rosas *et al.*, 2003a). Walker (2006) argues that in "by-passed (marginal)" regions, adoption levels of CPB varieties have been disappointing.

Additionally, some researchers argue that conventional plant breeders have defined breeding priorities without considering farmers' opinion (Gallardo *et al.*, undated) and have neglected to address constraints facing small farmers living in low-potential or marginal agricultural areas (Humphries *et al.*, 2005; Morris and Bellon, 2004), where the interaction between genotype x environment pose a critical problem for broad-spectrum breeding and adoption (Humphries *et al.*, 2005).

[11] Mather *et al.* (2003) reported that some bean IVs receive market discounts of 7-15%.

Researchers have cited additional shortcomings of CPB, including inefficient testing procedures or inadequate farm-level testing (Morris and Bellon, 2004; Walker, 2006) and inefficient varietal release processes and escape of materials (i.e. materials that are not released, nor distributed to farmers and that are lost) (Walker, 2006). Consequently, these researchers argue that varieties developed through CPB are best suited for the growing conditions that exist in high potential agricultural areas.

Finally, some researchers[12] argue that CPB has caused a loss of biodiversity because it promotes the use of uniform varieties across wide geographic regions, which in turn increase the risk of crop losses due to diseases and insect pressure.

Recognizing these concerns, during the past decade, plant breeders have sought to more actively involve end users in the varietal development process (Morris and Bellon, 2004). These efforts seek to: 1) increase farmers' participation in varietal selection and the validation process and 2) facilitate farmers access to IVs adapted to their low potential growing conditions (Rosas *et al.*, 2003a). Numerous researchers have identified participatory approaches as a strategy for achieving these objectives (Almekinders and Elings, 2001; Atlin *et al.*, 2001; Ceccarelli *et al.*, 2000; Morris and Bellon, 2004; Rosas, 2001; Rosas *et al.*, 2003a, undated-a; Sperling *et al.*, 2001).

Participatory approaches include participatory varietal selection (PVS) and participatory plant breeding (PPB), as discussed in sections 3.2.3 and 3.2.4.

3.2.2.3 Bean CPB in Honduras

In the late 1950s, Honduras' national research program (*Secretaría de Recursos Naturales*) and Zamorano (*Escuela Agrícola Panamericana*) joined together to

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[12] Maredia, 2010. Personal communication.

implement a CPB program for beans. However, around 1960, Zamorano terminated its breeding program, leaving the national program as the only institution doing bean breeding. However, in the late 1980s, when Zamorano restarted its bean breeding activities, collaboration between the National Bean Program and Zamorano was reestablished (Escoto, 2006; Escoto, 2000; SAG, 2007).

Currently, the bean research program is implemented by Zamorano and the Honduran National Bean Program at DICTA (*Dirección de Ciencia y Tecnología Agropecuaria,* formerly the *Secretaría de Recursos Naturales*), in collaboration with the USAID-funded Dry Pulses CRSP (formerly the Bean/Cowpea CRSP), CIAT (Mather *et al.*, 2003), and other programs and universities of the region. Rosas (2006a) commented that the main objective of CPB is to increase food security.

Since 1960, 26 improved bean varieties have been released in Honduras,[13] five of which were developed using participatory approaches and, as expected, most were small red varieties. From the 26 varieties, 12 varieties were released between 1960 and 1989 and 14 have been released since 1990, when Zamorano restarted its bean breeding activities (Table 3.2).

These CPB bean varieties have been widely adopted by farmers in Honduras. Mather *et al.* (2003) found that in the two principal bean-producing regions of Honduras, 41-46% of bean farmers had adopted an IV and that adoption was neutral with respect to farm size. Additionally, using an expected utility framework, they estimated that adopters' bean income increased 7-16% and that investments in disease resistant bean research from 1984 to 2010 generated an *ex post* rate of return of 41.2%. However, Rosas

[13] From these 26 varieties, 15 were developed in collaboration with CIAT after 1980.

Table 3.2. Improved bean varieties released in Honduras. 1957-2005.

Name	Year of release[1]	Line ID	Seed color / Market class	Breeding method[2]
Zamorano	1957	Landrace selection	Small Red	CPB
Desarrural 1	1969	Landrace selection	Small Red	CPB
Danlí 46	1979	Landrace selection	Small Red	CPB
Acacias 4	1979/ 1980	FF11-10-1-CM-CM-CM(4-B)-CM	Small Red	CPB
Esperanza 4	1979/ 1984	G 76	Red Kidney	CPB
Porrillo Sintético	1979	n.a.	Small Black	CPB
ICA PIJAO	1979	n.a.	Small Black	CPB
Ilama	1982	BAT 1217	Small Red	CPB
Copán	1982	RAO 1	Small Red	CPB
Catrachita	1987	RAB 205	Small Red	CPB
Araulí 85	1985	RAB 39	Small Red	CPB
Oriente	1990	DICTA 57	Small Red	CPB
Dorado	1990	DOR 364	Small Red	CPB
Don Silvio	1992/ 1993	DOR 482	Small Red	CPB
Tío Canela 75	1996	MD 3075	Small Red	CPB
DICTA 113	1996/ 1997	DICTA 113	Small Red	CPB
DICTA 122	1996/ 1997	DICTA 113	Small Red	CPB
Amadeus 77	2003	EAP 9510-77	Small Red	CPB
Carrizalito	2003	EAP 9510-1	Small Red	CPB
Milenio	n.r.	SRC 1-12-1	Small Red	CPB
Aifi Wuriti	n.r.	EAP 9712-13	Small Black	CPB
Marcelino	n.r.	n.a.	Small Red	PVS
Cedrón	2003	PTC 9557-10	Small Red	PVS
Cayetana 85	2003	PRF 9653-16B-2A	Small Red	PVS
Macuzalito	2004	PPB 9911-44-5-13M	Small Red	PPB
Palmichal 1	2005	PRF 9707-36	Small Red	PPB
Nueva Esperanza 01	2005	DICZA 9801	Small Red	PVS
Cardenal	2005	MER 2226-41	Small Red	CPB
Deorho	2005	SRC 2-18-1	Small Red	CPB

Source: CIAT (2001b), DICTA (1987, 1998), Escoto, D. (2000, 2006), Martel-Lagos, P. (1995), PIF/EAP and DICTA/SAG (2002a, 2002b), PIF/EAP (2003), ASOCIAL Yorito-Sulaco-Victoria *et al.* (2004), ASOCIALAYO *et al.* (2005a, 2005b), PIF/EAP and DICTA/SAG (2005a, 2005b), and Rosas, J.C. (2006a).

[1] There are some discrepancies in the year when some of the IVs were released, as various authors cited different releasing years.

[2] CPB= conventional plant breeding; PVS= participatory varietal selection; PPB= participatory plant breeding.

n.a. = not available; n.r. = not released; identical Line ID implies sister lines.

(2006a) estimated that in Yoro and Yojoa Lake regions (not main bean-producing regions), approximately 30% of the bean area was planted to CPB varieties. Adoption is lower in these regions because available CPB varieties have dark red seeds, which are less preferred by farmers. However, this is not a problem in some areas of the Yojoa Lake, where dark red varieties are preferred.

3.2.3 Participatory Varietal Selection (PVS)

3.2.3.1 General characteristics

Participatory varietal selection (PVS) is a participatory approach through which farmers are involved in late stages of the breeding process (Morris and Bellon, 2004; Walker, 2006; Witcombe and Joshi, 1997). However, farmer participation is limited to selecting lines from among a few fixed (stable) key lines. A PVS program usually has three phases: 1) identification of farmers' needs; 2) search for suitable materials[14] to test with farmers (or the provision of breeding lines with acceptable seed plant types); and 3) experimentation on farmers' fields (Witcombe and Joshi, 1997).

Phase 1 is particularly important because it reduces the possibility that farmers will be given unacceptable (by them) stable lines to test (Witcombe and Joshi, 1997). Therefore, farmers' early involvement is essential because scientists may not know the specific varietal preferences or needs of a particular group of farmers.

Phase 2 is necessary to identify suitable stable key lines for farmers to test, once their preferences have been assessed (Witcombe and Joshi, 1997). These authors note that

[14] The words "materials" and "lines" are used interchangeable and mean the same.

farmers could begin the process using various types of “starting” materials for experimentation, such as:

a) Already released cultivars, which will expose the farmers to the pool of released materials, which may increase the replacement rates of new cultivars. Also, governmental or non-governmental organizations could procure seeds in sufficient quantities for testing with other farmers (Witcombe and Joshi, 1997).

b) Advanced or fixed lines (homogeneous/stable materials) are most commonly used in PVS initiatives. By participating in assessing advanced lines, in principle, farmers can influence the selection of cultivars to be released because these materials are in the final evaluation phase of the breeding process. Farmers can be involved in various ways. Most commonly, farmers plant these materials in a common field so they can evaluate them without leaving the community. Alternatively, the material can be planted at a research station, with farmers visiting the station to evaluate the advanced lines (Witcombe and Joshi, 1997).

Phase 3 can be implemented in three different ways: 1) scientists can plant the identified cultivars in farmers’ fields with little or no involvement of farmers (however, farmers need to be involved in Phase 2 to be participatory); 2) scientists can provide the identified cultivars to farmers to manage the trials with little or no involvement of scientists; and 3) any combination of the above (Witcombe and Joshi, 1997).

3.2.3.2 PVS strengths and weaknesses

Strengths

Researchers have identified two strengths of PVS:[15] 1) increased biodiversity and 2) reduced likelihood of offering farmers unacceptable varieties.

First, probably the biggest effect that a PVS program may have is on increasing varietal biodiversity (Dorward *et al.*, 2007; Witcombe *et al.*, 2001; Witcombe and Joshi, 1997). Biodiversity is a broad concept that can be evaluated using different indicators. Witcombe and Joshi (1997) proposed that biodiversity can be evaluated by assessing (a) the replacement rate among cultivars (biodiversity over time), (b) the total number of cultivars per area, and (c) the proportion of the area that an IV occupies in a given region. They argue that PVS can increase varietal biodiversity (using these indicators) in a region.

Second, PVS reduces the likelihood of offering potentially unacceptable varieties to farmers (Witcombe and Joshi, 1997) because it uses a selection criteria based on traits that are important to the local community and it better target local environmental conditions (Elings *et al.*, 2001).

Witcombe and Joshi (1997) reported that through the use of farmer-managed participatory research methods in varietal trials, the Crops Programme of the Krishak Bharati Cooperative Indo-British Rainfed Farming Project (KRIBP) was able to identify three cultivars of chickpea, two of rice, one of maize, and two of black gram that were preferred by Indian farmers. The most revealing result was that the recommended CPB cultivars were rarely, if ever, preferred. Instead, all the preferred cultivars (except for one of rice and one of black gram) were obtained from outside the project area. Finally, Witcombe *et al*. (2001) found that PVS also increased rice biodiversity in Nepal and

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[15] These strengths are also strengths of PPB.

India and Almekinders and Elings (2001) noted that PVS trials can quickly answer farmers' immediate need for better germplasm, that these trials are relatively easy to conduct, and that with relatively modest efforts, these trials can have important impact on the community.

Weaknesses

Researchers have identified the following three weaknesses of PVS: 1) farmers may not be able to identify a suitable line to select; 2) farmers' needs may not be considered during early (segregating) stages of selection; and 3) PVS is a non-cyclical process (i.e. farmers may receive a set of materials only once).

First, it is possible that with PVS, farmers can't identify acceptable materials (Witcombe and Joshi, 1997) because (a) farmers are given a limited (usually small) number of lines to choose from so in the early stages of varietal development some materials are never evaluated by farmers and (b) PVS assumes that at least some of the lines produced by the formal sector (which are provided to farmers) are well adapted to farmers' niche environments and meet their preferences, which is not always the case (Ceccarelli 2000).

Second, the PVS experiences provide little information on farmers' needs for within-variety genetic heterogeneity because, as mentioned above, the materials used in PVS are improved varieties or stable lines. Hence, they offer little genetic variability for farmers to choose from (Almekinders and Elings, 2001). Moreover, farmers' exclusion of early stages of the breeding process limits their potential to gain knowledge about plant breeding methods.

Third, Ceccarelli (2000) noted that because PVS lacks the cyclic nature of plant breeding, which utilizes a continuous flow of genetic material from one stage to another, it is not clear if the participating farmer or community will have another chance to participate in PVS. These concerns, in part, led to the development of participatory plant breeding.

3.2.3.3 Bean PVS in Honduras

According to Almekinders and Elings (2001); Mejia (2006) and Rosas (2006a), PVS prepares farmers to implement PPB because it can quickly meet farmers' immediate needs for germplasm, is relatively easy to conduct, and farmers can 'save' 1-2 years of research (because they start the process with advanced lines). Hence, these benefits provide a strong incentive for farmers to participate.

The PVS program was implemented in the departments of Yoro, Comayagua and Santa Bárbara. In Yoro, the program was implemented with Zamorano and the *Fundación de Investigación Participativa de Honduras* (FIPAH, a Honduran NGO) as collaborating institutions. In the Yojoa Lake region (which includes the departments of Comayagua and Santa Bárbara), Zamorano and the *Programa de Reconstrucción Rural* (PRR, another NGO) were the collaborating institutions.

To implement the PVS program, it was required that the participating farmers 1) be organized, and 2) have some knowledge about on-farm trial management. In both regions, farmers were already organized into CIALs (Local Agricultural Research Committees) and worked with FIPAH and PRR in other agricultural activities prior the establishment of the project. These farmers learned about on-farm trial management when the CIALs started. Therefore, the institutions decided to implement PVS with these farmers because they were already organized and knew about trial management (Jimenez, 2006; Mejia, 2006; Rosas, 2006a).

Initially, maize was the crop used to implement the PVS project. Later, beans were also included in this project. In order to teach farmers breeding concepts, training was provided *in situ* and at Zamorano. The institutions used a "learning by doing" methodology to teach farmers, i.e. farmers first learn about a specific topic in a room and then they go to the field to practice it (Rosas, 2006a). Among the topics taught were: seed production, evaluation and selection of lines, trials management, and genetic resources characterization (useful to identify differences between lines). These are the same topics taught when the PPB project was established; however, PPB training included additional topics.

3.2.4 Participatory Plant Breeding (PPB)

3.2.4.1 Why PPB?

As mentioned above, several researchers argue that adoption levels of CPB varieties have been disappointing in marginal regions (Walker, 2006), that breeders have both defined breeding priorities without considering farmers' opinion (Gallardo *et al.*, undated), and they have neglected to address constraints faced by small farmers living in marginal agricultural areas (Humphries *et al.*, 2005; Morris and Bellon, 2004). Furthermore, inadequate farm-level testing procedures, inefficient varietal releasing processes, and escape of materials have been pointed to as weaknesses of CPB (Morris and Bellon, 2004; Walker, 2006). Participatory varietal selection methods have the limitation that, sometimes, potentially acceptable (by farmers) materials can't be identified (Witcombe and Joshi, 1997). Also, farmers' exclusion from the early stages in the breeding process may limit their knowledge of the process and thereby limit their influence on which varieties are released. Therefore, in an effort to overcome some of these weaknesses, researchers have suggested PPB as an alternative method for developing improved varieties (Almekinders and Elings, 2001; Atlin *et al.*, 2001; Ceccarelli *et al.*, 2000; Elings *et al.*, 2001; Morris and Bellon, 2004; Rosas, 2001; Rosas *et al.*, 2003a, undated-a; Sperling *et al.*, 2001; Walker, 2006).

3.2.4.2 General characteristics

Participatory plant breeding is a participatory approach through which farmers are involved in the breeding process, including the initial stages when early generations are selected (Ceccarelli *et al.*, 2000). Given that the process for selecting early generations may vary--depending on the breeder, the crop, and the crossing system used--PPB may take several forms. However, the key is that farmers are included in early stages of the breeding process, in contrast to PVS in which farmers are generally only involved in choosing from among advanced (or already released) lines (Ceccarelli *et al.*, 2000; Witcombe and Joshi, 1997).

Given that PPB involves close farmer-scientist collaboration for improving varieties, the various modes of farmer participation in PPB can be thought as points along a continuum representing different levels of interaction (Morris and Bellon, 2004). As the same authors state, these points can be characterized depending on how farmers and scientist interact to set objectives, take decisions, share responsibilities for decision-making, and generate products; which affects 1) the stage of the breeding process when farmers are involved (in PPB is early in the process); 2) the locations where the trials take place (can be on research stations, farmers' fields, or both); and 3) the design and management of the germplasm evaluation process.

3.2.4.3 PPB strengths and weaknesses

Strengths

Researchers have identified the following strengths of PPB: 1) increased biodiversity (similar to PVS); 2) increased knowledge about breeding; 3) farmers are empowered; and 4) improved (PPB) varieties may be adopted early and women's opportunities to participate in groups are increased.

Increased biodiversity. As with PVS, the biggest strength of PPB is its potential to increase biodiversity. PPB has increased biodiversity in Sub-Saharan Africa, where more than one-half of the breeders associated with the Eastern and Central Africa Bean Research Network and the Southern Africa Bean Research Network are utilizing PPB to breed new bean varieties. In Ethiopia, four bean varieties developed using PPB were released between 2002 and 2003, three more are in the pipeline, and two were recommended for region-specific usage. In Northern Tanzania, farming communities, in collaboration with one research institute, have selected nine bean varieties that were targeted for seed multiplication in 2006; and in Southern Uganda, two varieties have been identified (CIAT, 2006). In addition to this, intra-community diversity is also increased since varieties are developed for each (or a few) communities.

In Latin America, *Macuzalito*, the first bean variety officially released using the PPB approach, was released in Honduras in 2004 (CIAT, 2001b; Humphries *et al.*, 2005). Humphries *et al.* (2005) reported that before releasing *Macuzalito*, three additional advanced lines were tested, two of which were kept for local usage and the other was discarded because of agronomic deficiencies. In Honduras, one additional PPB variety (*Palmichal 1*) was released in 2005 and one additional variety will be released soon.

Farmers' knowledge about the breeding process. Humphries *et al.* (2005) contends that the benefits from PPB should not be measured only by the development of new improved varieties. In addition, it is important to take into account the skills that farmers develop by participating in the process. For example, they argue that farmers participating in PPB apply the knowledge acquired to their own field (e.g. pest control techniques, high quality seed, improved harvesting and storage techniques), which may increase their yields, income, and food security. With greater knowledge about breeding, farmers are better able to communicate with scientists,[16] not only professional breeders (Halewood *et al.*, 2007; Jimenez, 2006; Mejia, 2006; Rosas, 2006a). Additionally, PPB makes use of the traditional knowledge of farmers, elevating the profile of that knowledge and creating incentives to continue using and developing it (Halewood *et al.*, 2007).

PPB also empowers farmers. Morris and Bellon (2004) suggest that PPB empower farmers to maintain germplasm (of landraces) that they value (which also increases biodiversity) and involves them in the development of new varieties that are adapted to the specific environments that the farmers face.

Early adoption. Finally, several authors suggest that PPB can lead to earlier adoption of IVs, that reduces the time required for developing these varieties (Rosas,

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[16] Several farmers have participated in regional meetings with presentations about the PPB initiative and one of them was awarded a prize for his presentation.

2006a; Witcombe *et al.*, 2003), and that PPB can be structured to provide opportunities for women to participate (Halewood *et al.*, 2007; Rosas, 2006a).

Weaknesses

Among the weaknesses, researchers have identified the following: 1) high overall and per variety cost; 2) complex training is required (learning breeding techniques is more difficult); 3) high cost to farmers; and 4) potential to reduce biodiversity.

High overall cost of PPB. Given that PPB focuses on developing varieties for specific niches, these varieties usually will only be adopted by farmers in similar niche environments. Therefore, the cost per variety is increased. Additionally, because PPB targets specific environments, scaling up the project to the regional or national levels could require large investments in resources (Morris and Bellon, 2004) and may not be economical to implement one PPB project in each niche environment.

Complex training. As with PVS, farmers also need to learn about the breeding process in order to be able to participate in the project. Therefore, an investment in training is necessary to insure the success of PPB. Training costs associated with PPB are higher than for PVS because farmers involved in PPB need to learn how to make selections in the early stages of breeding, in contrast to PVS, where farmers only evaluate advanced lines (e.g. yield is a trait that is selected in late stages of breeding, not in early stages).

High cost to farmers. PPB requires farmers to invest their time, intellectual capital, and sometimes even primary resources (e.g. land, labor, and capital). The amount invested increases with the level of farmer participation in the process--the earlier the stage in which farmers are involved, the more investment they will be required to make (Morris and Bellon, 2004).

Reduced biodiversity. Finally, PPB could reduce genetic diversity if only a few of the new varieties are kept in the community, or if these new varieties replace old existing ones (Morris and Bellon, 2004). Despite this, loss of biodiversity may be concentrated to a community (or a few communities), not a large region as with CPB.

3.2.4.4 Bean PPB in Honduras

In Honduras, researchers who are using participatory bean breeding methods make little or no distinction between PVS and PPB (Mejia, 2006; Rosas, 2006a). The bean PPB initiative was initially carried out in the Departments of Yoro, Comayagua, Santa Bárbara, and more recently in El Paraíso.[17] The bean PPB project was first launched in the department of Yoro in 1999, using segregating populations as starter material. This location was selected mainly because Zamorano had been collaborating with the *Fundación de Investigación Participativa de Honduras* (FIPAH, a Honduran NGO) and the CIALs since 1993 to implement participatory varietal selection of beans, and participatory corn breeding (Jimenez, 2006; Rosas, 2006a). The funds for the project were provided by the Bean/Cowpea CRSP (now Dry Grain Pulses CRSP), the Participatory Research and Gender Analysis Program (PRGA, a CGIAR/CIAT program), and the University of Guelph from Canada.

After establishing the bean PPB project in Yoro; Zamorano and FIPAH launched a second bean PPB project with CIALs located in the Yojoa Lake region (which included

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[17] El Paraíso region was excluded from the analysis because there were no outputs to evaluate at the moment of the study (the project was in early stages).

the departments of Comayagua and Santa Bárbara). However, FIPAH withdraw from this region after identifying the *Programa de Reconstrucción Rural* (PRR) as a potential collaborator for Zamorano and the CIALs in that region (Jimenez, 2006; Mejia, 2006; Rosas, 2006a). Since then, PRR has been the NGO in charge of the project in this region.

In the Yojoa Lake region, the bean PPB project was launched in 2000, using segregating populations as starting material. Funding for this project was provided by the PRGA for the period 2000-2003. Since 2003, funding has been provided by the Norwegian NGO CIPRES (*Centro de Investigación y Propuestas Económicas y Sociales*) and the Spaniard NGO ACSUR (*Asociación para la Cooperación con el Sur*) (Rosas, 2006a).

Selection of farmers

In both regions, the bean PPB project was implemented with farmers who were already organized in CIALs and had participated in varietal selection. The researchers felt that farmers who knew about varietal selection would more easily understand the PPB methodology, including its similarities and differences with PVS. However, the project was not imposed--the NGOs and the CIALs decided together which CIALs were going to participate in the PPB project. As a result, the most experienced CIALs were selected to participate in the PPB initiative (Jimenez, 2006; Mejia, 2006; Rosas, 2006a).

Training provided

As with PVS, a "learning by doing" process was used to train the farmers--farmers were exposed to the theory and then practiced these topics in the field. Topics that had already been taught under the PVS project were reinforced during PPB training. Additional topics included: crop management; the breeding process, which included crosses, evaluation of lines at different stages of the crop cycle (e.g. pod filling, mature and harvesting), and selection techniques (pre- and post-harvest); and the PPB methodology. In addition, the farmers visited Zamorano to learn about greenhouse bean production (mainly used for crosses), to evaluate lines at the research station and to learn about trial management (Jimenez, 2006; Mejia, 2006; Rosas, 2006a).

Farmers' participation

In Honduras, the bean PPB project involves farmers in the early stages (F3 generation) of the breeding process. First, when the first trial (which includes a high number of segregating lines) is sent to farmers, it is evaluated in the NGO's field, typically located close to the communities. This reduces costs, as only one field needs to be maintained and farmers from different communities can visit the field to assist in the evaluation phase.[18] Second, the following trial (selections from the first trial) is managed and evaluated in each community. This is usually done in a common field (owned by the CIAL or lend by a particular farmer), where the evaluation process continues until few advanced lines are selected. Finally, advanced lines are evaluated at individual farmers' fields.

However, the PPB process doesn't start when farmers receive the segregating populations from the formal breeding institution at Zamorano. Rather, PPB starts when farmers met to identify (diagnose) problems in their current varieties and decide what traits they want to improve and how they are going to do it (Rosas, 2006a). Specifically, PPB farmers participate in determining the advantages and disadvantages of their varieties, deciding what traits need to be improved in these varieties, selecting among

[18] The same trial could be used for many CIALs to initiate the PPB process.

segregating populations and advanced lines, increasing seed of the chosen varieties prior to their release (to make seed available to other farmers at the moment of release), and participate in the release process (Rosas, 2006a).

3.2.5 Outcomes of PVS and PPB

In Yoro, at the moment of the study (2006), three bean PVS varieties have been developed by the CIALs that evaluated stable bean lines (>F6 generation) provided by Zamorano: *Cayetana 85* and *Cedrón* (released in 2003) (Jimenez, 2006; Rosas, 2006a), and *Marcelino* (not oficially released) (Jimenez, 2006). In the Yojoa Lake region, one bean PVS variety was developed: *Nueva Esperanza 01* (released in 2005) (Mejia, 2006; Rosas, 2006a). Fewer varieties have been released in the Yojoa Lake region because: 1) the PVS project started later in this region; and 2) one of the NGO staff, who was in charge of the project, left without notice. Hence, the advanced lines that were being evaluated were lost.[19]

Using the PPB methodology, farmers, in collaboration with NGOs and Zamorano, have developed two bean PPB varieties: *Macuzalito* (released in 2004) in Yoro, and *Palmichal 1* (released in 2005) in the Yojoa Lake region (Jimenez, 2006; Mejia, 2006; Rosas, 2006a). In this study, PVS varieties are considered PPB varieties and no distinction between PVS and PPB will be made in evaluating the benefits of PPB.[20]

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[19] Information from the informal group discussions prior to the survey implementation.

[20] This was done because of the similarity between both methodologies and the limited number of observations (if we were to distinguish between PVS and PPB varieties, the sample number per variety type would be reduced). The bias generated by this assumption is minimal because the major differences are between conventional and participatory methods.

Recognizing that early maturity is a trait desired by farmers because it helps to reduce the negative effects of droughts during the production cycle, the conventional breeding program at Zamorano started to include earliness when selecting lines. Furthermore, Zamorano increased the use of landraces (as parents) in its crosses in an effort to incorporate traits preferred by farmers, including earliness, seed color (market value), thickness of the cooked broth, and adaptation to marginal environments (Rosas, 2006a). Finally, Rosas (2006a) mentioned that, after PPB was implemented, adoption of both CPB and PPB varieties increased in these regions and women began to participate in the field activities (female participation was estimated at around 30%).

3.3 Agronomic characteristics of PPB varieties

This section includes only the primary characteristics of some of the PPB varieties, including resistance to different diseases, tolerance to abiotic factors, days to flowering and maturing, seed weight, seed color, and culinary value. However, as information was not available for all PPB varieties, Table 3.3 only shows information for three of these varieties and the following discussion is based on this information only.

Among the three PPB varieties described in Table 3.3, *Macuzalito* is the only one that is not resistant to bean golden yellow mosaic virus (BGYMV), which can cause 100% loss of the crop if its incidence is high. However, this (lack of) characteristic may not be a problem since the variety was developed for use at medium altitudes within the

Yoro region.[21] *Macuzalito* is resistant to anthracnose, rust and powdery mildew, common diseases at medium to high altitudes.

In contrast to *Macuzalito*, *Palmichal 1* and *Nueva Esperanza 01* are resistant to BGYMV but have medium resistance to other (fungal) diseases. Both *Macuzalito* and *Palmichal 1* have medium tolerance to drought. *Macuzalito* is ready for harvesting slightly later than the other two varieties, since it reaches flowering and maturity[22] 2-4 days later. All varieties in Table 3.3 have similar seed weight (of 100 seeds), seed color, and culinary characteristics.

One additional point is worth mentioning. *Palmichal 1* is the only PPB variety (among all six varieties) that was purified using molecular markers. The SCAR marker SR2 was use to select individual plants with the *bgm-1* gene, which indicates the plant is resistant to BGYMV (ASOCIALAYO *et al.*, 2005b).[23]

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[21] BGYMV is more problematic at altitudes below 1,200 m because the temperatures are higher and the inoculum sources and vector populations are abundant (Rosas, 2003c).

[22] It is important not to confuse maturity with harvesting day. The latter happens 10-12 days after maturity.

[23] Plants with this gene were used to produce enough seed for the release process (which was given to farmers attending this event).

Table 3.3. Major agronomic characteristics of selected participatory bred varieties,* Yoro and Yojoa Lake regions, Honduras, 2006.

Variety name	Resistance to diseases**	Tolerance to	Days to Flowering	Days to Maturity	Weight (gr) of 100 seeds	Seed color	Culinary value
Macuzalito	*High to*: Anthracnose, Rust and Powdery Mildew; *Low to*: Angular Leaf Spot and BCMV	*Medium to*: Drought and Low Fertility	40-41	72	22-24	Small light red	Good
Palmichal 1	*High to*: BGYMV; *Medium to*: Angular Leaf Spot	*High to*: High temperature; *Medium to*: Drought	36-38	66-68	23-24	Small light red	Good
Nueva Esperanza 01	*High to*: BGYMV; *Medium to*: Anthracnose and Angular Leaf Spot	n.a.	36-38	68-70	23-24	Small dark red	Good

Source: Rosas (2006a); Mejia (2006); Jimenez (2006); ASOCIAL Yorito-Sulaco-Victoria *et al.* (2004); ASOCIALAYO *et al.* (2005a, 2005b).

n.a. = not available.

*Information about Cedrón, Cayetana 85 and Marcelino was not available.

** BGYMV = Bean Golden Yellow Mosaic Virus; BCMV = Bean Common Mosaic Virus.

3.4 Comparison between CPB, PVS and PPB methodologies

While all of the methods described above (CPB, PVS or PPB) could be used to develop bean varieties (or any crop), the selection of a specific (or tailored) method will depend on the desired objectives. For example, if breeders want to develop varieties adapted to a wide range of environments and for high potential areas, CPB is the best methodology to follow. In contrast, if breeders want to develop varieties for niche environments and with specific traits, PVS or PPB may be the best alternatives to implement.

The stages where farmers participate will determine the methodology that is being used. Farmers could participate as early as in the selection of source of germplasm or as late as in the evaluation of advanced lines or could not participate at all (Halewood *et al.*, 2007). As was mentioned by Morris and Bellon (2004), farmer participation can be thought of as points along a continuum; ranging from two extremes (no farmer participation to no breeder participation) and with many different possible approaches to plant breeding between these extremes (Figure 3.3).

Each of these methodologies will likely result in different outcomes and require different levels of investment. For example, yield performance and adoption of these varieties could differ. Witcombe *et al.* (2003) reported that in farmers' fields in India, a maize PPB variety yielded more and had better grain quality than local landraces. Additionally, this variety was earlier to mature, compared to CPB varieties. Witcombe *et al*. (2003) and Lilja and Ashby (2002) state that these advantages should increase the speed of adoption and adoption ceiling of the PPB varieties, compared to CPB.

	CPB		PVS		PPB	
	F	**S**	**F**	**S**	**F**	**S**
Selection of source of germplasm		*		*	*	*
Trait development[1]		*		*		*
Segregating lines evaluation		*		*	*	*
Advanced lines evaluation		*	*	*	*	*

Notes: CPB = conventional plant breeding; PVS = participatory varietal selection; PPB = participatory plant breeding; F = Farmer; S = Scientist.

[1] Includes crosses.

SOURCE: Modified from Morris and Bellon 2004; and Halewood *et al.* 2007

Figure 3.3. Comparison of bean breeding methodologies implemented in Honduras, based upon farmers' participation during the breeding process.

Another different outcome is the time required for developing varieties. For example, it usually takes between 6-7 years to develop a bean variety using CPB (Rosas, 2006a); 4-5 years to develop a variety using PPB; and is estimated that it could take approximately 2-3 years to develop a bean variety using PVS (Mejia, 2006; Rosas, 2006a). However, PPB and PVS times exclude the time required to develop the segregating (F3) or advanced (F6) lines farmers will need to start the selection process. Hence, the real time to develop PPB and PVS varieties is longer than the one indicated above.

Finally, the cost of each program will be different. If we compare PVS and PPB, PVS will require less investment in training and field trials because it starts with advanced lines. Therefore, there are fewer lines to evaluate and fewer breeding stages are required. However, the process utilizes less of farmers' traditional knowledge, farmers learn less about the breeding process than under PPB, and farmers still need to invest time, land, labor and (sometimes) capital (Table 3.4).

Table 3.4. Comparison of bean breeding methodologies based upon outcomes and investments, Honduras, 2006.

	Methodology[3]		
Details	**CPB**	**PVS**	**PPB**
Expected yield in marginal areas[1]	same/lower	same/higher	higher
Adaptation to diverse environments	wide	niche	niche
Expected adoption rate in marginal areas	low	med-high	high
Women participation in field activities	none	varies	varies
Years required to release a bean variety after lines are received	5-6	2-3	4-5
Cost to farmers[2]	none	low	med-high
Usage of farmers' traditional knowledge	none	low	high
Knowledge farmers gain about the breeding process	none	low	med-high

Source: Rosas, 2006a; Mejia, 2006; Witcombe et al., 2003; The Author.
[1] Compared to landraces; [2] Cost includes time, land, labor and capital;
[3] CPB = conventional plant breeding; PVS = participatory varietal selection;
PPB = participatory plant breeding.

3.5 Impact evaluation methods

Different impact evaluation methods have been used to assess the benefits of PPB. Lilja and Ashby (2002) assessed PPB's impact using three criteria--economic benefits to farmers from adoption (production changes), improvements in farmers' human and social capital, and the increase in efficiency of the research process due to feedback from farmers to scientists. These authors found that the adoption rate of PPB varieties was greater than for CPB varieties. However, they identified methodological constraints in conducting a benefit-cost analysis because the economic benefits of PPB are difficult to quantify.

Other authors have assessed the impact of PPB through its effect on biodiversity (CIAT, 2006; Humphries *et al.*, 2005; Joshi and Witcombe, 2003) and have identified potential problems[24] in measuring adoption and diffusion rates and estimating the benefits attributable to adoption of CPB varieties (Morris and Heisey, 2003), which can also be a problem when evaluating PPB. The increase in the speed of the adoption process, the increase in the adoption ceiling, and producer surplus models have been used to assess the benefits of PPB and its impact on farmers (Lilja *et al.*, 2002). Finally, cost-effectiveness analysis has also been carried out to assess the impact of PPB (Witcombe *et al.*, 2005).

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[24] Potential problems include defining modern varieties, estimating the area planted to these varieties, estimating adoption at a given point in time, estimating diffusion through time (which can be measured in several ways), estimating farm-level yield gains, accounting for changes in crop management practices, and accounting for non-yield benefits.

3.6 Chapter summary

Honduras has two growing seasons, the *Primera* and the *Postrera*. If beans are planted in the *Primera*, they are produced mainly to multiply seed for farmer's *Postrera* planting, which is the main season for bean production. Almost 40% of Honduras' total bean production is carried out by small farmers with less than five hectares of land. It has been reported that these farmers sell 55% of their surplus production, usually to middlemen. While farmers prefer small red beans, black beans account for 5% of the country's production. As in most Central American countries, there are several players in the supply chain; including farmers, local traders, regional traders, producer's associations, wholesalers, two national institutions, and retailers.

Typically, small farmers cultivate beans in marginal areas, apply low levels of purchased inputs, and have limited access to markets. Additionally, abiotic and biotic constraints reduce farmers' yields and income, which threaten household's food security. To ease these constraints, plant breeders have sought to develop improved bean varieties that are adapted to a wider range of environments, resistant to diseases, tolerant to high temperatures, and have a higher yields potential.

Conventional plant breeding has been very effective in producing input-responsive, broadly-adapted varieties of crops. In Honduras, since 1960, 21 CPB bean varieties have been released; yet, these varieties have not been adopted by many farmers in marginal growing environments because of inefficient seed dissemination channels which limit farmers' access to good quality seed, the lower market quality of IVs compared to landraces, and because the IVs are poorly adapted to the production systems used by small farmers in some growing environments. Some researchers contend that IVs have not been adopted by many farmers in marginal environments because the CPB program defined breeding priorities without considering farmers' opinion and neglected to address constraints facing small farmers living in marginal agricultural areas.

These shortcomings have led to the development of participatory plant breeding methods. The establishment of CIALs has played an important role in the implementation of participatory methods. First, in 1993-95, a PVS methodology was implemented with farmers who were CIAL members. This was done because CIAL farmers had experience with trial management and group work. Under this project, they learned about varietal selection and other topics related to bean production, and officially released three bean varieties (one additional variety was not officially released).

In 1999, a PPB project was introduced as a way to more directly involve farmers in the breeding process. It is envisioned that PPB will facilitate the development of more stable, higher yielding, and more adaptable varieties, which will result in higher adoption among farmers in marginal growing environments; thereby increasing farmers' income and food security. Farmers that participated in the PVS project were selected for this project because they had experience with varietal selection; hence, it was expected they could easily learn about PPB. Under this project, farmers have officially released two bean varieties with resistance to different diseases, tolerance to several abiotic factors, and good market and culinary values. Additionally, one of these varieties (*Palmichal 1*) was purified using molecular markers to select plants with resistance to BGYMV.

Several evaluation methods could be used to assess the impact of PPB projects. Among these are estimating: the economic benefit to farmers who adopted the varieties, the improvement in farmer's human and social capital, the increase in the efficiency of the research process, adoption rates, the effect on biodiversity, the increase in the rate of adoption, producer surplus models, and cost-effectiveness analysis. Furthermore, researchers have identified several potential problems that need to be considered when measuring adoption and diffusion rates, when estimating the benefits attributable to adoption of bred varieties, and when carrying a cost-benefit analysis to assess the impact of PPB projects.

CHAPTER 4. RESULTS AND DISCUSSION

This chapter presents an analysis of the socioeconomic characteristics of the PPB and non-PPB farmers, strengths and weaknesses of PPB, PPB benefits to farmers and net present value.

4.1 Farmers' socioeconomic characteristics

A main interest of the study was to determine if there were differences in the socioeconomic characteristics of PPB and non-PPB participants. However, given that the PPB project was established in two (very different) regions of the country[25] and was implemented by two NGOs,[26] it is also necessary to disaggregate farmers' characteristics and responses by region.

With respect to socioeconomic characteristics of PPB and non-PPB participants, there were few significant differences (Table 4.1). However, for many variables there were significant differences between the sample of farmers (i.e. all farmers in each region) in Yoro and Yojoa Lake regions.

PPB and non-PPB participants were similar with respect to the age and gender of the household head, household size, dependency ratio, number/percent of adults with more than three years of education, participation in other agricultural projects prior to PPB, number of livestock units, and remittances received. However, there was a significant difference in the education of the head (10% significance level). On average,

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[25] Yoro is located in a dry region while Yojoa Lake is located in a wet region.
[26] PPB was implemented by FIPAH in Yoro and by PRR in the Yojoa Lake region.

Table 4.1. Summary of family socioeconomic characteristics by PPB participation and region, Honduras, 2006.

Characteristics	PPB-participant? No	PPB-participant? Yes	P-value[4]	Region (all farmers)[5] Yoro	Region (all farmers)[5] Yojoa Lake	P-value[4]	Total
Age of head (years)	44	45	0.7909	45	44	0.8100	44
Gender of head (% male)	94	85	0.1293	83	96	**0.0259	90
Education of head (No. years)	2.9	3.7	*0.0845	3.0	3.6	0.2211	3.3
Household size	4.9	5.3	0.3766	4.7	5.5	*0.0938	5.1
No. members 0-9 years old	1.2	1.1	--	1.2	1.0	--	1.1
No. members 10-15 years old	0.5	1.2	--	0.7	1.0	--	0.9
No. members 16-60 years old	2.9	3.0	--	2.5	3.4	--	3.0
No. members older than 60	0.2	0.1	--	0.3	0.1	--	0.2
Dependency ratio[1]	0.37	0.39	0.7238	0.42	0.35	0.1314	0.38
No. of adults[2] with >3 years of education	1.7	1.6	0.6156	1.2	2.1	***0.0057	1.7
Share of all adults with >3 years of education (%)	50	55	0.4887	41	64	***0.0014	52
Participation in other agricultural projects prior to PPB (% YES)	32	40	0.3961	50	22	***0.0024	36
No. of Tropical Livestock Units[3]	1.3	1.1	0.7735	2.0	0.4	**0.0157	1.2
Received remittances in 2005 (% YES)	25	20	0.5757	22	22	1.0000	22
Have access to credit (% YES)	51	85	***0.0001	76	61	*0.0992	69
Number of sample observations	53	55	--	54	54	--	108

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] Dependency ratio is calculated by dividing the number of individuals under 16 years of age plus the number of individuals over 60 years of age by the total number of individuals in the household.

[2] Adults refers to family members who are older than 15.

Table 4.1 (cont'd).

[3] Tropical Livestock Units calculated using FAO conversion tables.

[4] P-value is for a mean-difference t-test between PPB participants vs. non-participants and Yoro farmers vs. Yojoa Lake farmers, assuming equal variances.

[5] Includes both PPB and non-PPB farmers. -- = not tested; ***=significant at a 1% level; **=significant at a 5% level; *=significant at a 10% level.

the head of PPB households had 0.8 more years of education than the head of non-PPB households.

Regarding the gender of household head, 90% of the households in the sample were male-headed. While the differences for PPB and non-PPB households were not statistically significant, fewer male-headed households were observed in the Yoro region (83% vs. 96%, 5% significance level) suggesting there are more female-headed households in this region. Also, in Yoro, the percent of female-headed households was higher for PPB participants (27% vs. 7%).[27]

For the total sample, the average household size was 5.1 individuals. While the difference in household size for PPB and non-PPB households was not statistically significant, households in the Yojoa Lake region had an average of 0.8 more individuals than households in the Yoro region (10% significance level). In addition to household size, the age-distribution of household members was accounted for by estimating a dependency ratio. The dependency ratio[28] for the total sample was 0.38, meaning that there were a little more than 2.6 non-dependent individuals for every dependent in the household. However, the differences in dependency ratio by PPB participation and across regions were not statistically significant (Table 4.1).

[27] For each region, the means for PPB and non-PPB participants were estimated. In Yoro, 73% of PPB households and 93% of non-PPB households were male-headed (p-value = 0.0526). In contrast, in the Yojoa Lake region, 97% of PPB households and 96% of non-PPB households were male-headed (p-value = 0.9167). Estimations not included in Table 4.1.

[28] A higher dependency ratio implies that there are more dependants (individuals younger than 16 or older than 60) in the household; therefore, each non-dependant individual has to provide for/take care of more dependants.

For the total sample of households, an average of 1.7 adults[29] had more than three years of education (Table 4.1). This represented approximately one-half of all adults in the household, which could be accounted for by the fact that there were two (one in each region) small-sized towns (with schools) relatively close to the communities.[30] While the differences in the number of adults with more than three years of education in the household and the share of all adults that this number represented were not statistically significant between PPB and non-PPB households, households in the Yojoa Lake region had almost one more adult with more than three years of education (1% significance level) and the share of all adults with more than three years of education was higher (64% in Yojoa Lake vs 41% in Yoro, 1% significance level).

While there was no significant difference between PPB and non-PPB participants with respect to prior participation in agricultural projects and number of livestock units, a higher percent of farmers in Yoro (50% vs. 22%) had participated in other agricultural projects (1% significance level) and had more livestock units (2.0 vs. 0.4, 5% significance level).

Finally, access to credit was statistically significant by PPB participation and across regions. More PPB farmers had access to credit (85% vs. 51%) compared to non-PPB farmers (1% significance level). This was because PPB participants had access to

[29] Adults refers to family members who are older than 15. Adults are different than non-dependent members because adults include members who are older than 60.
[30] See Table 2.1 For distance (km) from each community to these towns (closest market place).

credit through their respective CIAL or ASOCIAL,[31] which is one of the benefits from participating in these farmer groups. Farmers located in the Yoro region had more access to credit (76%) than farmers in the Yojoa Lake region (61%, 10% significance level). This was because, on average, communities in the Yoro region were closest to Yorito, the closest small town with services, while communities in the Yojoa Lake region were more distant to Taulabé, the closest small town with services (9km vs. 13km, respectively; see Table 2.1 for details). Therefore, farmers in the Yojoa Lake region may face higher transaction costs in accessing credit.

4.2 Bean PPB project's strengths and weaknesses

Advocates of PPB argue that it has the potential to generate improved bean varieties that are better adapted to niche environments, have traits more desired by farmers and produce higher yields in these environments, compared to CPB varieties. As a result, farmers would adopt these varieties more rapidly than CPB varieties. PPB could also increase biodiversity, increase farmers' knowledge about the breeding process, and increase women participation in field activities.

However, compared to CPB, PPB projects are more costly for breeders to implement, as they require greater farmers' knowledge about breeding techniques, and require farmers to incur additional costs (land, labor). Furthermore, farmers and scientists may have different perceptions about a PPB project's strengths and weaknesses, as discussed below.

[31] There is one CIAL per community. CIALs in the Yoro region are members of a the ASOCIAL Yorito-Sulaco-Victoria located at FIPAH's headquarter in Yorito, while CIALs of the Yojoa Lake region are members of the ASOCIALAYO located at PRR's headquarter several miles away from the closest small town, Taulabé.

4.2.1 Farmers' perceptions of the project's strengths and weaknesses

Farmers likely chose to participate in the PPB project because they expected to benefit from it, i.e. farmers' expected utility from participating is greater than or equal to their expected utility from not participating. Specific reasons for participating may include the reputation of the organizations implementing the project, their expectation of increased knowledge and greater access to improved varieties (with higher yields), or just because of the satisfaction that the participant gains from interacting with other farmers. However, once the farmers start participating, they may decide to withdraw from the group (or stop participating) if they perceive their expectations are not met. Participating farmers were asked several questions about their expectations from the project and why they decided to participate. Additionally, they were asked several questions about the training they received, their satisfaction with the role of collaborating institutions, and their perceived weaknesses about the project.

Farmers' expectations. When asked about the objectives of the project, PPB farmers (n=54) mentioned that one of their objectives was to release improved bean varieties (61% of them). Additionally, most PPB farmers expected to learn new bean farming techniques that they could perhaps apply in their fields (48%), while fewer expected to learn about bean breeding itself (44%). This is interesting because, despite breeding being the main activity of the project, most farmers expected to learn more about farming techniques than about bean breeding.

Participation. PPB participants (n=55) reported that they decided to participate in the project because they wanted to learn about the breeding process (45%), were interested in learning more about bean farming techniques (29%), and wanted to have more access to bean varieties (15%). Additionally, 7% of the farmers said they participated because they liked to be in a group.[32]

Given that the PPB project was implemented as one of the CIAL's activities, it is possible that farmers who participated did so because they felt obligated to do so. However, less than two percent of the farmers responded they had participated in the PPB project because it was required by the CIAL.

These results suggest that farmers may have perceived that, from participating in the project,[33] they would obtain specific benefits (e.g. increased knowledge, access to more bean varieties). This could be because Zamorano, FIPAH, and PRR all had a good reputation with the PPB participants (from previous projects) and in the region. Therefore, one of the strengths of the project is its reputation --farmers perceived the PPB project as good because these specific institutions implemented it.

Training. Regarding the focus of the training, 71.8% of the topics were related to PPB techniques, which included learning about specific diseases in order to be able to incorporate resistance into the new varieties through selection, crosses, trials management, steps to follow to release varieties, and the selection process itself. A little over 23% of the topics were related to general bean production techniques, which included post-harvest management, soil quality analysis, and harvest residues management. It is difficult to separate these two categories, as farmers need to know

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[32] Approximately 40% of the participant farmers had already participated in at least one agricultural project prior to the PPB project, which suggest more farmers may like to be in groups than what they reported.

[33] Participation means that farmers were fully participating in the CIAL activities; i.e. were active members of the CIAL.

about production in order to do breeding. While farmers reported that they learned a lot about both PPB and bean production, they felt that they learned slightly more about PPB (68%) than bean production (65%). These results show a clear strength of the project, that it fulfilled farmers' expectations.

Satisfaction regarding the role of collaborating institutions. As expected, perceived weaknesses varied depending on the project area. In Yoro, FIPAH was the collaborating NGO; while in the Yojoa Lake region, PRR was the collaborating NGO. Zamorano collaborated directly with farmers in both regions (e.g. training provided by Zamorano staff) and provided technical and financial support to the NGOs and CIALs.

Satisfaction with Zamorano's support. In Yoro, almost 35% of PPB participants felt that Zamorano needed to increase its support to the project, including greater financial assistance, additional seed of PPB varieties, additional "learning by doing" training, more PPB varieties, and training in other farming activities in addition to PPB. In contrast, only 4% of farmers in the Yojoa Lake region felt that Zamorano needed to increase its support to the project (Table 4.2).

While 15% of the respondents in Yoro felt that Zamorano needed to increase its direct contact with (or number of visits to) farmers, none of the farmers in Yojoa felt a need for more direct contact with Zamorano. This suggests that farmers in the Yojoa Lake region were more satisfied with Zamorano's role in the PPB project and with their NGO than farmers in Yoro. This was also confirmed by the percent of farmers who felt that Zamorano has done a good/excellent job in implementing the project: 35% in Yoro vs 57% in Yojoa Lake (Table 4.2).

Satisfaction with the NGO's support. Participant Yoro farmers, who received support from FIPAH, reported that this NGO needed to increase its direct contact/more visits with/to them (28%) and that it also needed to increase its current support (16%), including providing additional financial help, more seed of PPB varieties, additional training, more PPB varieties, and support for additional activities besides PPB. Additionally, 24% of Yoro farmers said FIPAH has done a good/excellent job in the bean PPB project.

In contrast, none of the Yojoa Lake PPB participants, who received support from PRR, reported that the NGO should increase its direct contact/more visits with/to them. However, 14% of them said PRR needed to increase its current support and 21% said the NGO needed to continue its support by providing financial help, more seed of PPB varieties, and training (Table 4.2).

The limited number of visits FIPAH staff made to PPB participants in the Yoro region could be due to the large number (35) of CIALs with which this NGO was working. Thus, probably FIPAH had limited staff available to fully attend to the farmers' needs. In contrast, because PRR worked with only 12 CIALs, its direct contact with farmers was higher. An additional factor could be the limited resources these NGOs had for the work they are doing.[34]

[34] As was reported by the NGOs staff.

Table 4.2. Participant farmers' suggestions (% of farmers) regarding the role of Zamorano, FIPAH, and PRR in the participatory breeding project,[1] Honduras, 2006.

	Yoro Region (%)		Yojoa Lake Region[2] (%)	
Suggestions	**Zamorano**	**FIPAH**	**Zamorano**	**PRR**
Satisfied/ has done good or excellent job	34.6	24.0	57.2	60.7
Continue support	3.9	4.0	14.3	21.4
Increase support	34.6	16.0	3.6	14.3
Increase direct contact/ visits	15.4	28.0	0.0	0.0
Others[3]	11.5	28.0	24.9	3.6
Number of sample observations	26	25	28	28

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] Zamorano = Escuela Agrícola Panamericana; FIPAH = Fundación para la Investigación Participativa de Honduras; PRR = Programa de Reconstrucción Rural.

[2] The Yoro Region included communities in the department of Yoro, while the Yojoa Lake Region included communities in the departments of Comayagua and Santa Bárbara.

[3] For Zamorano, "Others" included the provision of farm inputs, helping with seed production, making available information of new varieties, and helping poorest communities. For FIPAH and PRR, "Others" included the provision of farm inputs, motivation of farmers to continue research, and finding technological packages together rather than recommending pre-conceived ones.

Weaknesses. PPB farmers from the Yojoa Lake region[35] who participated in an informal group discussion mentioned several (perceived) weaknesses of the bean PPB projects, including:

- Two of the bean PPB varieties released were susceptible to diseases, particularly, angular leaf spot, anthracnose, and rust.

[35] Not done in Yoro.

- Seed of PPB varieties was not available. Therefore, they felt that there was a need to increase seed production (of PPB varieties) in order to make the new varieties more widely available and to increase adoption.
- The PPB project needed to include the breeding of black varieties, as only red varieties were targeted for improvement. This is understandable because of the site's proximity to Guatemala, where black beans are preferred.
- Some farmers perceived that women participation was low in this region and that there was a need to increase gender equality.[36] Reasons given for low female participation included "machismo," women's lack of time, their loss of interest in the project, and the submissive nature of female spouses.

In both regions, non-PPB participants reported they had not become members of the CIAL because they haven't heard about the CIAL's work (31% of respondents), don't have the time (26%), don't like to participate in groups (23%), or had heard there have been problems within CIAL members (8%). Furthermore, eleven farmers were previously members of the CIAL, but were not members at the time of the interview.[37] These farmers reported that they stopped participating in the CIAL because there were problems within the CIAL (55% of respondents), or had no time to participate (27%), among other reasons.

[36] The data indicate that more female-headed households participated in the Yoro region (see footnote 23 for details).

[37] While these farmers were treated as non-PPB participants in most of the analysis, they were treated as participants for the yield analysis since it is highly likely that they obtained benefits from participating in the CIAL, which could have had an effect in their yields.

These results (i.e. farmers' satisfaction with the role of participating institutions and their perceived weaknesses of the project) suggest the need for Zamorano and the NGOs to seek additional resources to enhance their capacity to better meet farmers' needs. Additionally, they indicate that farmers still depend heavily (technologically and financially) on Zamorano and the NGOs to maintain the project, and hope that these institutions will either continue or increase their support to them; which may limit the long-term sustainability of the project and its scaling up to other regions of the country.

If the project is to be sustainable (i.e. continue without or with minimal participation of outside institutions), these weaknesses will need to be addressed. This may be done by increasing CIAL's capacity to generate revenues from its activities (all CIAL activities, not only PPB) as a way to reduce its financial dependence on outside institutions. This will allow Zamorano and NGOs to use all of their resources to provide technical[38] support.

4.2.2 Zamorano's staff perceptions of the project's strengths and weaknesses

Zamorano's participation in the project has been stable since it was initiated in 1998. Because of this, Zamorano's bean breeder had good insights regarding the strengths and weaknesses of the PPB project. Regarding strengths, he mentioned the project reduced the time required for farmers to adopt new bean varieties, increased the effectiveness of the trials, and increased the probability of adoption of the PPB varieties. Among the weaknesses, he mentioned the need of scaling PPB up in order to have a more

[38] In contrast, currently Zamorano provides fund to the NGOs to implement trial and cover travel and training expenses.

widespread impact, the current experimental stage of PPB, and its dependence on CPB to succeed.

Time required for adoption. Among the strengths, the breeder at Zamorano believed that participatory methods reduced the time required for adoption of new PPB varieties because farmers become familiar with the varieties prior to release. Therefore, farmers who are going to adopt a specific variety will do so before (or during) the release stage, in contrast to CPB varieties that first are released and then distributed among farmers.

Effectiveness of trials. According to Zamorano's bean breeder, PPB increases the cost-effectiveness of implementing the trials. Because PPB farmers manage the field trials, more trials can be carried out in more locations with different specific environmental characteristics. The PPB trails also have a secondary impact on the conventional breeding program, since breeders can test some of their lines in these trials--thereby increasing the number of sites where promissory lines are evaluated.

Probability of adoption. The breeder also mentioned that released PPB varieties have a higher possibility of adoption, compared to CPB varieties. The reasons are similar to the reasons noted above. Since farmers become familiar with the varieties ahead of time because they help to develop them, they recognize their benefits and adopt them rapidly. Finally, participating farmers are likely to encourage their friends and family to adopt the PPB varieties prior to and/or after they are released because they are familiar with the varieties' benefits.

Potential for widespread impact. Among the weaknesses, Zamorano's breeder noted that in order to have a significant impact in a region (or the country), it is necessary to simultaneously implement PPB in several locations. Therefore, considerable monetary and human resources are needed. Human resources include collaborating farmers, NGOs, and, particularly for Zamorano, additional extension agents in order to increase the level of interaction between Zamorano and NGOs and with farmers directly. The Zamorano breeder estimated that one full-time extension agent is needed to visit (five days per month) each location to provide sufficient direct contact with farmers and NGO staff. However, given Zamorano's tight budget, resources are not available to provide the needed level of support.

Experimental stage. Zamorano's breeder pointed out that the participatory approach is still in the experimentation stage. Because Zamorano has not been able to scale up PPB to other regions in the country; it continues working in the same areas where the project started.

Dependence on traditional plant breeding. Finally, the breeder mentioned that PPB is highly dependant on Zamorano's conventional breeding program because it has the necessary resources (greenhouses, fields and trained staff) needed to carry out all stages of the breeding process. While farmers have some knowledge about this process (which they have done in practice), the first stage of the breeding process requires making crosses. Despite farmers' (basic) training on this area, they can't carry out this activity by themselves because they lack the experience and resources to do so.[39]

4.2.3 NGOs' staff perceptions of the project's strengths and weaknesses

Staff from both NGOs (FIPAH and PRR) had similar perceptions regarding the strengths and weaknesses of the PPB project. Since they worked hand-on-hand with

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[39] From our sample, only 4.6% of farmers knew very well how to do bean crosses.

participant farmers, they were able to provide key insights that could help improving current PPB projects and the scaling up of PPB. They mentioned that some of the strengths are farmers' increased capacity to do research and the participatory-based methodology of PPB. Among the weaknesses, they included the need for additional funding and PPB's dependence on CPB.

4.2.3.1 Fundación de Investigación Participativa de Honduras, FIPAH

Farmer capacity building. Among the strengths, FIPAH's staff mentioned that the knowledge that farmers gain through PPB training is one of the key strengths of the project. Because these trained farmers can (in principle) spread this knowledge, the training benefits are extended to other farmers. Additionally, PPB enhances research capacity in the communities--farmers can apply the experience gained (enhanced capacity) by participating in the PPB project to independently conduct experiments to solve their crop production-related problems.

Funding. FIPAH considered the lack of funds as the primary weakness of the project. Without additional money, FIPAH focused on maintaining its current agenda, rather than on expanding it. Additionally, they suggested that more work should be done to increase the diffusion of the generated knowledge because it had not spread as widely as expected. This is understandable as farmers/CIALs lack the funds to show their results/provide seed to farmers in other communities. While FIPAH could better diffuse farmers' acquired knowledge to other communities is by employing the most experienced farmers as extension agents, this would require additional funds.

4.2.3.2 Programa de Reconstrucción Rural, PRR

PPB and CIAL methodologies are similar. PRR staff considered that one of the strengths of the project is that the PPB methodology is similar to the research methodology used by the CIALs. Therefore, it can be easily implemented through the CIAL farmers who already have experience conducting research. However, specific (additional) training is required for farmers to understand and implement the PPB process.

Dependence on traditional plant breeding. Among the weaknesses, PRR staff pointed out that CIALs still depend on Zamorano for making the initial crosses. According to the Zamorano breeder, given farmers' (and PRR staff's) limited knowledge about crossing techniques and the difficulty of doing bean crosses, there is no alternative. However, PRR proposed that Zamorano train farmers and/or staff to make bean crosses, so when Zamorano's participation ends, the bean PPB project will be able to continue. Finally, PRR staff mentioned that both PRR and farmers still require the collaboration of a permanent extension agent from Zamorano to address their concerns and help in the project.

4.3 The costs of bean PPB

The marginal[40] cost of PPB was estimated by adjusting data that Zamorano's bean breeder provided, regarding the cost of the CPB program. This was done because there were no records of PPB costs and Zamorano's breeder provided good cost

[40] Marginal costs, refer to the extra cost needed to be able to do crosses and supply segregating materials for PPB to start.

estimations at different stages of the CPB process (detailed below). Therefore, the marginal cost of PPB was estimated as a percentage of the CPB costs.

The CPB process is divided into several stages: crosses, F1, F2, F3, F4, F5, F6 generations,[41] nurseries,[42] seed increase, farmer trials, and varietal release. Table 4.3 summarizes marginal CPB and PPB costs per stage. For details about cost estimation, see Table A.3.

Zamorano's staff do crosses under greenhouse conditions. The breeder at Zamorano estimated that at least 50 crosses are necessary to develop a single new variety for release.[43] In order to do these 50 crosses, one person needs to work for two 3-hour days at a cost of $2.50/day. This activity is done during the first 3 hours of the day to avoid high temperatures, which will abort the crosses.

The offspring (F1 generation) of these crosses are planted under greenhouse conditions to produce enough seed for the following stage. It was estimated that this activity costs $500 per 1,000 m^2. Each subsequent stage (i.e. F2-F6 generations) is planted under field conditions and only the best lines are advanced from one stage to the next.[44] Rosas (2006a) estimated that the cost of each stage from F2 to F6 generations was $500 per 1,000 m^2.

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[41] F1 means the seed is the offspring of the cross. F2 means the seed is the offspring of the F1, and so on. After F6, the lines are entered into different nurseries for evaluation.

[42] To estimate cost per nursery, the average number of locations, lines and replications per line per nursery were used. See Table A.2 for details.

[43] One variety will be released several years after crosses are made.

[44] Advancing a line means that in a particular stage, the line is selected because of its good traits and is planted again (instead of discarding or storing it in a germplasm bank).

Table 4.3. Summary of marginal costs of conventional (CPB)[1] and participatory (PPB) plant breeding of beans. Honduras, 2006.

		Marginal cost per variety	
Year[2]	**Stage[3]**	**CPB ($)**	**PPB ($)**
1	Crosses	5	5
1	F1 generation	5	5
1	F2 generation	38	38
2	F3 generation	135	68
2	F4 generation	68	34
3	F5 generation	34	17
3	F6 generation	17	8
	Nurseries:	*(multi-locations)*	*(single location)*
	LINAF/VIROS	51	n.a.
	VIDAC	140	n.a.
	ECAR	900	n.a.
4	COVA	500	200
4	Seed increase	1,000	250
	Farmer trials	2,000	n.a.
	Releasing process:		
5	Demonstrative field	5,000	741
5	Field day	2,120	318
5	Seed for distribution	3,000	750
5	Paperwork	500	500
	Total marginal cost	**15,511**	**2,933**

Source: The author, based on information provided by Rosas (2006a); Escoto (2006); and Zamorano's bean program (PIF) database. For details of each value, see Table A.3. n.a. = not applicable.

[1] Marginal costs because they refer to the extra cost of developing one variety. CPB costs do not reflect the total cost of developing a variety through CPB (because they exclude fixed costs).

[2] Year is based on the PPB process, not the CPB process.

[3] Crosses to F3 done by Zamorano; all other stages done by CIAL farmers.

After stage F6, the selected CPB lines are entered into the first of several nurseries.[45] These nurseries include many lines that come from different sources (e.g. batch of crosses or breeding programs). Therefore, the lines coming from the 50 crosses mentioned above represent only a percentage of the total number of lines in these nurseries.

For the first nursery (LINAF and/or VIROS), Rosas (2006a) estimated it costs \$500 per 1,000 m^2. In contrast, the cost of all subsequent nurseries varies depending on the number of locations where they are evaluated each year, the number of lines per nursery, and the number of repetitions per line. For the VIDAC and ECAR nurseries, the number of locations, the number of lines per nursery, and the number of repetitions per line were obtained from historical data from Zamorano's breeding program (Table A.2).[46] For the COVA nurseries, the number of locations and the number of repetitions per line were also obtained from historical data. However, Zamorano's breeder suggested using an average of six lines per COVA, which was more representative than the historical (CPB) data.

Zamorano and DICTA scientists estimated that each VIDAC and COVA nursery costs \$300 to implement, while each ECAR nursery costs \$600 to implement. As the nurseries are used to collect data about the adaptability of the CPB lines to different environments, it is necessary to plant these nurseries at several locations throughout the

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[45] Nurseries are sequential and start with LINAF/VIROS. Once selected, the lines are put in the next nursery, VIDAC. Later, are included in the ECAR and COVA.

[46] Table A.2. show that, on average, the VIDAC has been planted in 12 locations and has had 103 lines with one repetition per line. The ECAR has been planted in 8 locations and has had 16 lines with 3 repetition per line. Finally, the COVA has been planted in 5 locations and usually includes 2 repetitions per line.

country to collect representative data regarding the lines' adaptability to different environments. However, under PPB, the only nursery used by farmers is the COVA.[47]

After COVA, the best (one or two) CPB line(s) is(are) evaluated under farmer conditions (i.e. farmer trials). For the farmer trials, large quantities of seed are produced on the experimental station. Rosas (2006a) mentioned that 10 farmer trials are usually conducted in different regions of the country and each cost $200. Under PPB, farmers do not incur in farmer trial costs. Since the breeding process (except the initial crosses and stages F1 to F3) is done in farmer fields, it is not necessary to repeat this stage.

Finally, for each CPB variety, a demonstrative field is planted prior to the release stage at a cost of $1,250. Once the lines planted in the field approach maturity (~75 days after planting), farmers, NGOs staff, and government officials are invited to attend the field day, at a total cost of $530.[48] This activity is done to officially release the (CPB) variety. At the field day, farmers are able to see the crop in the field, taste cooked beans, and take a sample of seed with them.

A similar process is needed for PPB varieties. NGO staff mentioned that, for PPB, the total cost of a demonstrative field plus the field day was approximately $1,059 (Lps. 20,000); less than the cost for CPB varieties because the magnitude is smaller. Therefore, using the same proportions from the CPB costs,[49] it was estimated that a demonstrative

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[47] Under PVS, farmers start with VIDAC or ECAR nurseries, in which case, they do not receive segregating lines. For PPB, we assume farmers start with segregating lines.

[48] The field day takes place where the demonstrative fields were planted.

[49] For CPB, the total cost of both the demonstrative field and the field day is $1,780. The cost of the demonstrative field represents 70% of this value and the cost of the field day the remaining 30%. These proportions were used to estimate the value of each of these two stages under PPB.

field costs $741 (one demonstrative field is planted for each PPB variety) and the field day costs approximately $318.

Producing CPB seed for distribution at the field day cost approximately $3,000 per 910 kg of seed (Rosas, 2006a). However, under PPB, less seed (25% of 910 kg) is produced to distribute during the field day.

The PPB costs are lower that the costs described above for CPB because farmers carry out most of the steps in the breeding process themselves and most research-related costs are lower (e.g. cheap labor, fewer trials, less seed) than for the CPB process. To estimate the PPB costs, the following assumptions were made:

(1) Although farmers aren't involved in stages crosses to F2 (i.e. they start using F3 lines); these costs are considered in full since they are required to produce F3 lines that farmers use.[50]

(2) The cost of stages F3 to F6 is assumed to be 50% of the CPB cost, since PPB farmers usually test one-half the number of lines, compared to CPB.

(3) While an average of six COVAs are used for CPB development, only two COVAs are necessary in PPB since, by definition, PPB lines are developed for adaptation to niche. Therefore, fewer nurseries are needed to test the adaptability of PPB lines.

(4) Although it cost $1,000 to increase seed of advanced CPB lines for planting in the farmers' trials, under PPB, this stage will only cost 25% of this value because (a) no farmer trials are planted and (b) less seed is needed for the following stages. However, it is necessary to increase seed of PPB lines for planting the bean field that is used during

[50] That is, it is necessary to "pay" for these stages to be able to get F3 lines.

the “field day” and to plant the field that produce the seed that is distributed during the “field day”.

(5) No farmer trials are planted. Since all previous stages were done under farmers’ conditions, farmers already have enough information about the lines that will be released.

Table 4.3 shows that the estimated marginal cost of developing a bean variety through PPB is approximately 20% of the marginal cost of developing a variety through CPB. However, these estimations only reflect the marginal cost of including PPB as an activity to Zamorano’s CPB program[51] and the cost incurred by each CIAL to implement PPB.[52] Given that Zamorano’s breeding program has been functioning for many years, the marginal cost of making crosses and developing F1-F3 materials for PPB is relatively small (Table 4.3). However, if PPB is to be established without a CPB program (i.e. the farmers make their own crosses), the cost of making the crosses, and stages F1 and F2 must be included.[53] The marginal cost for producing a PPB variety was expected to be lower than the cost of producing a CPB variety--since PPB varieties are developed for niche environments, the number of locations and the cost of the process itself is drastically reduced.

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[51] The CPB costs in Table 4.3 and Table A.3 are marginal cost and were estimated only to be able to estimate the marginal cost of developing a PPB variety. Since the cost of salaries, infrastructure investments, and other fixed costs are excluded, the cost of developing a CPB variety is underestimated.

[52] Most of the costs described are included in the benefit-cost analysis as “breeding materials.” Labor costs are additional and are described in Section 4.5.1.

[53] In Honduras, the PPB projects receive segregating lines from Zamorano’s CPB program; therefore, investment (fixed) costs of stages prior to F3 are not accounted for. Instead, only the marginal costs of these stages are included in Table 4.3 and Table A.3.

4.4 The benefits of bean PPB to farmers

As described above, there are many ways that farmers could benefit from PPB. The following analysis focuses on the knowledge farmers gained about PPB which, in principle, could be applied to their own fields or could help insure the sustainability of the PPB projects; the effect on women participation in field activities, which have been said to increase with PPB; the exchange of bean varieties within and across the selected communities; and the characteristics of the PPB varieties released, and their adoption rate and yield differences.

4.4.1 Farmers' knowledge about PPB and farming techniques

To evaluate farmers' knowledge about PPB and farming techniques, a knowledge scale was constructed. For this, farmers were asked seven questions specifically related to PPB and other relevant topics (Table 4.4). These were open-ended questions and each answer was given a score between zero and two, depending on the quality of the answer.[54] Therefore, the maximum score a farmer could have was fourteen.

To construct the knowledge scale, the total score (sum of the seven questions) was divided by the total maximum points possible (fourteen), which generated a percentage of knowledge. For simplicity, each question was given the same weight. The knowledge scale provided a quantification of farmers' PPB knowledge.

To test the reliability of the knowledge scale, the Cronbach's alpha was computed. This test computes the inter-item correlations or covariances for all pairs of

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[54] For example, if the farmer was asked to explain what is the first step in order to breed a variety to make it resistant to diseases and his answer was to use pesticides, his answer was given a grade of zero (the correct answer would have been to cross the variety with another disease-resistant variety). To reduce bias, the author did the grading of all questions.

Table 4.4. Questions used to construct the PPB-knowledge scale. Honduras, 2006.

No.	Question	Expected answer (2 points)
1	If the CIAL wants to improve a traditional variety to make it resistant to a disease like Angular Leaf Spot, what are the first steps to start the breeding process?	Select a disease-resistant variety and cross it with the traditional variety; then follow the PPB process.
2	How do you cross two bean varieties to get a new one?	Select two flowers. By hand, open both flowers and transfer the pollen from one to the other. Finally, close the flower that received the pollen and label it.
3	How do you cross two maize varieties to get a new one?	Select two plants. Cut the male flower head from both plants. Collect the pollen from one of these plants (the father) in a paper bag and put it in the female flower head of the other plant (the mother) and seal it with the same paper bag. Label it.
4	What are the differences between fields planted with grain vs. clean seed?	With grain, there is lower germination rate, non-uniform flowering (hence harvesting), and lower yields. With clean seed, the opposite is true.
5	What are the differences between fields planted with segregating lines (F3) vs. using a variety such as Tío Canela 75?	With F3 plants, there is high variability in the crop. Some plants are bush-type, others are climbing-type; some may be black-seeded, others red-seeded. Flowering stage may not be uniform. With Tío Canela 75, the crop is uniform (bush-type, red seed, harvest at same time).
6	What field activities should be done to produce clean seed (not grain) from a bean variety?	Select a good field. At flowering, eliminate plants with different color of flowers. Also, eliminate infested/sick plants. At harvest, select the best plants for seed and avoid overdrying the seed.
7	If you are selecting plants for resistance to Angular Leaf Spot (or any disease), what field conditions are necessary to select resistant plants?	Any of the following: The disease must be present. The conditions for the disease (temperature, moisture, pathogen) must be present. I must see other plants infected while the one I'm selecting is not.

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

questions used in constructing the scale and assess the reliability of a summative rating scale composed of the questions (StataCorp, 2001).[55] This test show that the scale is reliable since the estimated correlation between the scale and the underlying factor it measures (i.e. PPB knowledge) is $\sqrt{(0.7984)} \approx 0.89$; where 0.7984 is the scale reliability coefficient (or alpha). Additional results of this test can be found in Table A.4.

The results show that the mean score of the PPB farmers was 41%, compared to 19% for non-participants. These differences were statistically significant (1% significance level) (Table 4.5). There were three reasons why non-participants could have known about PPB. *First*, 6% of the non-PPB farmers were members of the CIAL at some point in the five years previous to this study. Since PPB has been implemented for several years, they may have learned about the process during their participation. *Second*, the non-PPB farmers could have learned about PPB from attending CIAL meetings (where all members of the community are invited to attend). *Third*, two (Questions 4 and 6 in Table 4.4) of the seven questions used to construct the knowledge scale were not specific to PPB. Non-PPB farmers could have learned this information from their participation in other agricultural projects (32% of them reported participating in at least one agricultural project in the five years previous to this study). However, their inclusion in the scale was necessary since these topics were covered during the training received by PPB participants.

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[55] For more details about this test, please refer to the STATA 7 A-G manual, pages 19-24.

Table 4.5. Farmers' knowledge about plant breeding, by PPB participation and region, Honduras, 2006.

Variable	PPB participant? No	PPB participant? Yes	P-value[2]	Region[1] Yoro	Region[1] Yojoa Lake	P-value[2]
Knowledge (%)	18.6	41.3	***0.0000	45.3	37.7	0.1577
Number of sample observations	53	55		26	29	

Source: B/C CRSP Survey of PPB project in Honduras, 2006.
[1] Only compares PPB participants.
[2] ***=significant at a 1% level; **=significant at a 5% level; *=significant at a 10% level.

Finally, among PPB participants, the differences in PPB knowledge between farmers in the Yoro region and farmers in the Yojoa Lake region were not statistically significant (Table 4.5).

4.4.2 Trade of PPB varieties

It was expected that PPB participants would promote the use of PPB varieties within their communities and, if possible, across communities. However, given their limited (monetary) resources, it may be difficult for the farmers to promote PPB varieties in other communities. Because of this, only whether farmers ever traded[56] any PPB variety was analyzed, regardless of where this transaction took place.

The results suggest that, within the communities studied, 47% of the sample of PPB and non-PPB farmers have traded at least one PPB variety at some point in time. As expected, trade was affected by participation in the PPB project--more PPB participants reported trading these varieties, compared to non-participants (60% vs. 34%,

[56] By trade we mean whether a farmer has ever sold, given away, bought and/or received (for free) any PPB variety.

respectively). Additionally, trade in the Yoro region was higher than in the Yojoa Lake region (69% vs. 26%, respectively), which was not surprising since in this region the project was implemented earlier and more CIALs had released more varieties. All these differences were statistically significant at the 1% level (Table 4.6).

Table 4.6. Percentage of farmers trading participatory bred (PPB) varieties within studied communities, by PPB participation and region, Honduras, 2006

Detail	PPB-participant? No	PPB-participant? Yes	P-value[1]	Region (all farmers)[2] Yoro	Region (all farmers)[2] Yojoa Lake	P-value[1]	Total
				(% YES)			
Have ever traded PPB varieties	34	60	***0.0064	69	26	***0.0000	47
Have ever sold or gave away PPB varieties	11	47	***0.0000	44	15	***0.0006	30
Have ever bought or received PPB varieties	30	42	0.2121	52	20	***0.0005	36
Have ever sold PPB varieties	4	35	***0.0000	31	7	***0.0014	19
Have ever gave away (for free) PPB varieties	8	29	***0.0037	26	11	**0.0481	19
Have ever bought PPB varieties	15	9	0.3424	19	6	**0.0388	12
Have ever received (for free) PPB varieties	19	36	**0.0428	39	17	***0.0096	28
Number of sample observations	53	55	--	54	54	--	108

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] P-value is for a mean-difference t-test between PPB participants vs. non-participants and Yoro farmers vs. Yojoa Lake farmers, assuming equal variances. ***=significant at a 1% level; **=significant at a 5% level; *=significant at a 10% level.

[2] Includes both PPB and non-PPB farmers.

Given that trade was defined as either selling, giving, buying, or receiving seed of PPB varieties, it was important to analyze which of these transactions was the most common type of trade. As reported in Table 4.6, 28% of the sampled farmers reported receiving seed of PPB varieties for free, the most common type of trade. Additionally, more farmers in the Yoro region reported receiving free seed than farmers in the Yojoa Lake region (39% vs. 17%, 1% significance level).

As expected, the number of PPB participants receiving free seed was higher than for non-participants (36% vs. 19% respectively, 5% significance level). These differences are likely due to the fact that since PPB participants developed the varieties, they had direct access to this seed and usually receive it for free.

In contrast, purchasing seed of PPB varieties was the least common type of trade (only 12% of sampled farmers reported ever buying seed of these varieties).[57] Although the differences in the percent of farmers who reported purchasing seed were not statistically significant between PPB participants and non-participants, there were statistical differences between regions. More farmers in the Yoro region reported purchasing seed, compared to farmers in the Yojoa Lake region (19% vs. 6% respectively, 5% significance level) (Table 4.6).

These results suggest that there is still a need to increase farmers' access to PPB seed. Given that the most common form of trade was to have received free seed, if providing free seed is to continue, more seed must be made available to non-PPB

[57] Low purchases were expected because it is not common for farmers to purchase bean seeds. PPB farmers generally consider PPB varieties as being better than other varieties. Thus farmers should be willing to pay for seed of these varieties. However, they may not do so because receiving free seed may deter purchasing it.

participants and especially to farmers in the Yojoa Lake region so they can have greater access to these high-yielding[58] PPB varieties.

The results also suggest that there is a slightly more developed seed market in the communities of the Yoro region, since more farmers in this region reported purchasing seed. However, given the low percentage of farmers who purchased seed, selling seed may not be the most appropriate way to disseminate these varieties. Developing a commercial seed market will be challenging because (1) the crop is self-pollinated; therefore, farmers don't need to buy seed every season (and they seldom do it) and (2) the price of seed is higher than grain (the alternative to use instead of seed). However, while determining the best way to make available PPB seed to farmers is out of the scope of this study, it should be investigated in future research.

Although data about the quantity of seed traded were collected, it is not presented because some farmers reported large amounts of seed traded, which seemed unlikely. Because it is likely that these farmers provided information regarding the sales of grain, not seed, these data are omitted.

4.4.3 Adoption rate of PPB varieties in the communities

To estimate the adoption rate of PPB varieties, the total and average number of hectares planted to each variety type was estimated. Farmers were asked to provide the name of the bean varieties they planted in both the *Primera* and *Postrera* seasons of 2005, in each of their fields/plots. These data are analyzed by season, PPB participation, and region. In addition, farmers were asked whether they planted any PPB and/or CPB

[58] Quantitative yield benefits are shown in section 4.4.4.

varieties (from a list) within the five years prior to the study, which one they preferred most, and the reason why.

In the 2005 agricultural year, the most widely planted varieties were the traditional variety *Estica* and the PPB variety *Macuzalito* (Table 4.7). Among the CPB varieties, *Tío Canela 75* was planted most widely. However, the number of hectares planted to this variety was equal to only 11% of the area planted to *Macuzalito*.

Additionally, the number of hectares planted to *Estica* and *Tío Canela 75* was higher in the *Primera* season, while the number of hectares planted to *Macuzalito* was slightly higher in the *Postrera* season. Since the data reported in Table 4.7 refers to total number of hectares planted, the number of farmers who planted beans in each season directly affected this. Ninety-four farmers planted beans in the *Primera* season while only fifty-four farmers planted beans in the *Postrera* season[59]--mostly in the Yoro region because excess rainfall make planting beans difficult in the *Postrera* in locations in the Yojoa Lake region.[60]

As expected, traditional varieties were planted most widely (63 has), followed by PPB varieties (31 has) and, far behind, CPB varieties (4 has) (Table 4.8). Low adoption (4.1% of bean area) of CPB varieties was anticipated since the PPB projects were implemented in communities that had low levels of adoption of CPB varieties. In contrast, adoption of PPB varieties was high (31.6%) and similar to values that

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[59] The average number of hectares per farmer was 0.66 in the *Primera* and 0.67 in the *Postrera*.

[60] In the *Primera*, from a total of 94 farmers planting beans, 50 were from the Yojoa Lake region. In the *Postrera*, from a total of 54 farmers planting beans, only 11 were from the same region.

Table 4.7. Total area (ha) planted to each bean variety in Yoro and Yojoa Lake regions of Honduras in the 2005 agricultural year, by season.

Variety Name	Market class	Variety Type[1]	Area Planted (ha) *Primera*	*Postrera*	Total
Estica	Small Red	TRA	21.2	9.5	30.6
Macuzalito	Small Red	PPB	10.0	12.0	22.0
Concha Rosada	Small Red	TRA	5.5	2.3	7.8
Mano de Piedra	Small Red	TRA	7.5	0.0	7.5
Vaina Blanca	Small Red	TRA	4.4	0.4	4.8
Marcelino	Small Red	PPB	0.9	2.7	3.6
Carmelita	Small Red	TRA	0.7	1.9	2.7
Cuarenteño	Small Red	TRA	0.8	1.8	2.6
Tío Canela 75	Small Red	CPB	1.9	0.6	2.5
Nueva Esperanza 01	Small Red	PPB	1.4	0.4	1.7
Cincuenteño	Small Red	TRA	1.7	0.0	1.7
Cedrón	Small Red	PPB	0.9	0.8	1.7
Palmichal 1	Small Red	PPB	0.7	0.4	1.1
Cayetana 85	Small Red	PPB	0.4	0.7	1.1
Rosado	Small Red	TRA	0.0	0.7	0.7
Balín Rojo	Small Red	TRA	0.7	0.0	0.7
Balín	Small Red	TRA	0.7	0.0	0.7
Agua Buena	Small Red	TRA	0.7	0.0	0.7
Pedreño	Small Red	TRA	0.0	0.6	0.6
Dorado	Small Red	CPB	0.0	0.5	0.5
Carrizalito	Small Red	CPB	0.3	0.1	0.5
Seda	Small Red	TRA	0.4	0.0	0.4
Vaina Morada	Small Red	TRA	0.4	0.1	0.4
Armando	Small Red	TRA	0.2	0.2	0.3
Frijol Rojo	Small Red	TRA	0.0	0.3	0.3
Amadeus 77	Small Red	CPB	0.3	0.0	0.3
Chapín	Black	TRA	0.0	0.2	0.2
Talete	Black	TRA	0.1	0.1	0.2
Arbolito	Small Red	TRA	0.2	0.0	0.2
Zamorano	Small Red	TRA	0.2	0.0	0.2
Negrito	Black	TRA	0.1	0.0	0.1
Deorho	Small Red	CPB	0.1	0.0	0.1
Cardenal	Small Red	CPB	0.1	0.0	0.1
Total hectares (ha)			**62.4**	**36.0**	**98.4**
Number of sample observations			94	54	148

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] TRA= Traditional variety; CPB= Conventionally Bred variety; PPB= Participatory Bred variety.

Rosas (2006a), Jimenez (2006) and Mejia (2006) estimated. Farmers prefer one variety to another if the particular variety has a bundle of good characteristics instead of one particular trait. For example, although higher yields are desirable, farmers also like good market value, good cooking quality, and good plant architecture, among other traits (Table A.5).

In Yoro, 37.7% of the bean area was planted to PPB varieties, while in the Yojoa Lake region only 11.8% of the bean area was planted to PPB varieties (Table 4.8). The higher level of adoption in the former region could be attributed to several reasons including the year of release of the varieties (*Macuzalito*, the most planted variety in Yoro, was released one year prior to *Nueva Esperanza 01*, the most planted variety in Yojoa Lake);[61] the experience of the NGOs working in each of the regions (in Yoro, the NGO is larger and had been involved in PPB many years than the NGO in the Yojoa Lake region); and the agronomic characteristics of the varieties, particularly seed color. For example, *Macuzalito* has light-red colored seed, which is most preferred by farmers, compared to *Nueva Esperanza 01* which has dark-red colored seed.

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[61] Since *Macuzalito* was the first PPB variety released, it provided the necessary experience for the release of all following varieties. It took four years to release *Macuzalito* and five years to release *Nueva Esperanza 01*.

Table 4.8. Total area (ha) planted to each bean variety type in Yoro and Yojoa Lake regions of Honduras in the 2005 agricultural year, by season, PPB[1] participation and region.

Variety type planted	Season (all farmers)[2]		PPB participant?		Region (all farmers)[2]		Total	Percent
	Primera	***Postrera***	**No**	**Yes**	**Yoro**	**Yojoa Lake**		
				(# ha)				**(%)**
Traditional	45.4	17.9	32.7	30.6	45.0	18.4	63.4	64.4
Participatory bred (PPB)	14.2	16.9	10.4	20.6	28.3	2.8	31.1	31.5
Conventionally bred (CPB)	2.8	1.2	2.0	2.0	1.7	2.3	4.0	4.1
Total	62.4	36.0	45.1	53.2	75.0	23.5	98.5	100.0
Number of sample observations	94	54	73	75	87	61	148	148

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] PPB = Participatory Plant Breeding.

[2] Includes both PPB and non-PPB farmers.

The data reported in Table 4.9 suggest that farmers preferred to plant PPB varieties in the *Postrera* season. On average, farmers planted 0.31 hectares of PPBs in the *Postrera*, compared to 0.15 hectares in the *Primera* (1% significance level). Although the number of farmers who planted beans in the *Postrera* was lower, the average number of hectares planted to PPB varieties by each farmer was higher. Two reasons help to explain this finding. First, most of the farmers who planted beans in the *Postrera* season were located in Yoro, where high adoption levels were observed (37.7% of the bean area was planted to PPB varieties vs. 11.8% in the Yojoa Lake region). Second, in the Yoro region, as in most parts of the country, the *Postrera* is the main production season. Therefore, it was expected that farmers would plant more area in this season.[62]

Tables A.6 and A.7 show that farmers in Yoro increased their planting of PPBs from an average of 0.28 hectares in the *Primera* season to 0.38 hectares in the *Postrera*,

Table 4.9. Average area (ha) planted to each bean variety type in the 2005 agricultural year, by season. Honduras.

Variety type planted	2005 Season		P-value[1]	Total
	Primera	***Postrera***		
	(average # ha)			
Traditional	0.48	0.33	0.2030	0.43
Participatory bred (PPB)	0.15	0.31	***0.0049	0.21
Conventionally bred (CPB)	0.03	0.02	0.6477	0.03
Number of sample observations	94	54		148

Source: B/C CRSP Survey of PPB project in Honduras, 2006.
[1] P-value is for a mean-difference t-test between *Primera* vs. *Postrera* seasons, assuming equal variances. ***=significant at a 1% level; **=significant at a 5% level; *=significant at a 10% level.

[62] Generally, maize is the main crop planted in the *Primera* season.

while farmers in the Yojoa Lake region only increased their planting of PPBs from 0.04 to 0.06 hectares perhaps due to excess rainfall in the *Postrera*.

Among farmers who planted PPB varieties, *Macuzalito* was the most widely grown variety—the average number of hectares planted to this variety (0.31 has) was much higher than the number of hectares planted to any other PPB variety (Table 4.10). While there were no statistical differences in the average number of hectares planted to each PPB variety between seasons (Table 4.10), as mentioned above, PPB varieties were more widely grown in the *Postrera* season (Table 4.9).

Additionally, a surprising finding was that none of the PPB varieties released in the Yoro region were grown in the Yojoa Lake region and none of the PPB varieties released in the Yojoa Lake region were grown in the Yoro region (Table A.8). This may have been because each of these varieties was released for the specific environmental conditions in each region. Therefore, it is likely that they will not well adapt to other regions.[63] Despite this, Rosas (2006a) mentioned that the CIALs in the Yojoa Lake region were evaluating *Macuzalito* (released in and for the Yoro region) in their bean trials. If *Macuzalito* could adapt well to places with environmental conditions similar to Yoro, more farmers may adopt it (in the Yojoa Lake region) and the economic impact would be greater.[64]

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[63] This is especially true if the environmental conditions are different (which they are) because under similar conditions, the varieties could adapt well and produce good yields.

[64] This may be true since *Macuzalito* has better market value (i.e. seed color) than *Nueva Esperanza 01*, the most widely adopted variety in the Yojoa Lake region. Additional details about each variety can be found in Section 3.3.

Table 4.10. Selection of bean varieties among farmers who planted PPB[1] varieties in the 2005 agricultural year, by season. Honduras.

PPB variety planted	2005 Season *Primera*	2005 Season *Postrera*	P-value[2]	Total
	(average # ha)			
Macuzalito	0.29	0.34	0.5152	0.31
Marcelino	0.02	0.08	0.1757	0.05
Nueva Esperanza 01	0.04	0.01	0.2287	0.02
Cedrón	0.03	0.02	0.9111	0.02
Palmichal 1	0.02	0.01	0.4493	0.02
Cayetana 85	0.01	0.02	0.6783	0.02
Number of sample observations	35	35		70

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] PPB = Participatory Plant Breeding.

[2] P-value is for a mean-difference t-test between *Primera* vs. *Postrera* seasons, assuming equal variances. ***=significant at a 1% level; **=significant at a 5% level; *=significant at a 10% level.

Therefore, additional effort should be devoted to evaluating and promoting these varieties in other niche environments.[65]

Using the above information, a logistic adoption curve was estimated for PPB and CPB varieties for years 1996-2018, using the following formula (from Alston *et al*. 1998):

$$A_t = \frac{A^{MAX}}{1 + e^{-(\alpha + \beta t)}}$$

where A_t is the actual adoption rate (% of bean area) t years after the release of the variety (i.e. the year of the study); A^{MAX} is the maximum adoption rate, and α and β are parameters that define the path of the adoption rate that asymptotically approaches the

[65] This will be equivalent to PVS: CIALs in other locations could test adaptation of PPB varieties to their environments.

maximum. This curve can be generated with as little as three parameters: A^{MAX}, α and β. The expression above could be rearranged and written as a function of α, A^{MAX}, A_t and *t*:

$$\ln\left(\frac{A_t}{A^{MAX} - A_t}\right) = \alpha + \beta t$$

Since we know A^{MAX} and two combinations of A_t and *t* (adoption in year one and adoption at the time of the study), α and β could easily be estimated from the equation above. One disadvantage of this methodology is that the formula does not allow for the possibility of disadoption of the technology.

Mather *et al.* (2003) assumed different maximum adoption ceilings for IVs, depending on the region and season.[66] On average, they assumed the maximum adoption ceiling to be 31% of the bean area. However, the adoption rate averaged 52% in the four communities that developed the PPB variety *Macuzalito*.[67] Since adoption of PPB varieties was lower in the other five communities, it is possible that adoption could increase up to *Macuzalito's* adoption rates. Therefore, it is assumed that A^{MAX} = 52% for PPB varieties.[68] For CPB varieties, it is assumed that the current adoption rate is almost at the maximum since, before PPB was implemented in these communities, it was known that farmers were not adopters of IVs. Therefore, A^{MAX} = 5% for CPB varieties because it is not expected that farmers will increase their adoption of these varieties. Using this

[66] Adoption rate ranged from 22% to 37% of the bean area.
[67] Adoption rate averaged 32% in all nine communities. See Table 4.8 for details.
[68] Mather's *et al.* (2003) adoption rate was not considered because the adoption rate in this study was higher than what they had estimated.

information, α and β were estimated. For CPB varieties, $\alpha = -1.6944$ and $\beta = 0.3081$. For PPB varieties, $\alpha = -6.11165$ and $\beta = 2.1847$ (see Table A.9 for details).

Figure 4.1 shows that the maximum adoption rate for PPB varieties would be reached very fast. This is because, two years after the varieties were released, adoption was high.[69] For CPB varieties, adoption will not increase more than the current rate. The disadvantage of the logistic curve is that it does not account for potential disadoption that would be expected with any technology (e.g. new IVs could replace current ones).

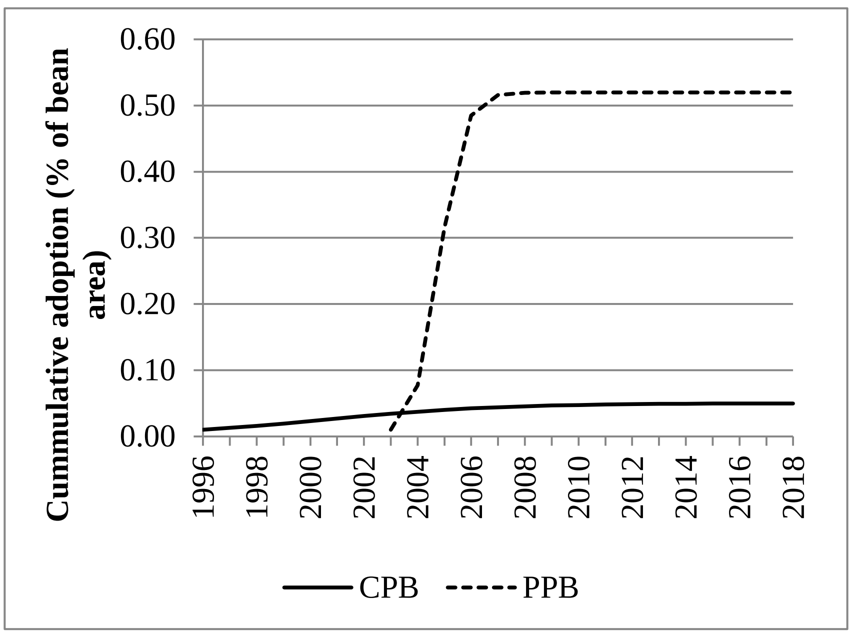

Figure 4.1. Logistic adoption curves for conventional (CPB) and participatory (PPB) bred bean varieties, Yoro and Yojoa Lake regions, Honduras, 2006.

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[69] Although this is true, the number of hectares planted to PPB varieties was not high. This was expected since PPB varieties are developed for niche environments.

4.4.4 Econometric estimation of bean yields determinants and empirical results

4.4.4.1 Econometric estimation

The factors associated with farmers' bean yield differences were analyzed for the 2005 agricultural year (i.e. two seasons together). The dependent variable (yields, in kg/ha) was obtained by asking farmers the area planted to each bean variety and the quantity of beans harvested from this area. The explanatory variables included in the linear regression were classified into four groups: project- and production-related variables, socioeconomic characteristics of the farmers/households, access to financial resources, and quasi-fixed variables. Each of the explanatory variables is explained below.

Project-related dummy (NO=0, YES=1) *variables*

- Participation in PPB. Participation in the project may have a positive or negative effect on yields. On the positive side, farmers could apply the knowledge gained through training (PPB farmers have been trained on bean production activities—not only breeding activities) to their production fields, hence obtaining higher yields.[70] On the negative side, participating farmers have to devote part of their time to PPB activities (e.g. meetings, field work, etc.), which could reduce the time available for their own field activities. This is particularly true if the CIAL is conducting research on many topics (besides PPB). In the sample, some farmers participated in the CIAL in the past, but were not participating in the project at the time of the study. In the yield regressions, these

[70] However, this may depend on the resources available. For example, farmers may know they should apply fertilizer or pesticides, but they may not be able to do this because they don't have the monetary resources or the product may not be available anywhere close.

farmers were included as participants since they received the benefits of the project (e.g. training).[71] Farmers who were participating in the project or who participated at some point in the past in the CIAL were assigned a value of 1, while farmers who didn't participate were assigned a value of zero.

- Planted a CPB variety. Farmers who participate in the PPB project have higher access to conventionally bred (CPB) varieties. Planting CPB varieties is expected to positively influence yields since, despite their potentially low adaptability to marginal environments,[72] they may still produce higher yields than traditional varieties (and perhaps participatory bred varieties). Farmers who planted CPB varieties were assigned a value of 1, while farmers who didn't plant CPB varieties were assigned a value of zero. The coefficient of this explanatory variable measures the magnitude of the change in yields between planting a CPB and a traditional variety, holding everything else constant.

- Planted a PPB variety. Many PPB advocates suggest that varieties developed by participatory methods are better adapted to niche (marginal) environments than conventionally bred varieties. Humphries *et al.* (2005) reported that one PPB variety (*Macuzalito*), yielded more than 2,000 kg/ha in field trials in 2002 (more than traditional and CPB varieties). It was expected that PPB varieties would yield more than traditional varieties and possible more than CPB varieties. Farmers who planted PPB varieties were assigned a value of 1, while farmers who didn't, were assigned a value of zero. The

[71] Prior to this section (i.e. in all other descriptive tables), these farmers were included as non-participants since participation refers to "current" participation. However, they are included as participants in the yield regression because they benefitted from the project in the past.

[72] As stated by some PPB advocates.

coefficient of this explanatory variable measures the magnitude of the change in yields between planting a PPB and a traditional variety, holding everything else constant.

Production-related dummy (NO=0, YES=1) *variables*

Since quantitative information regarding the use of purchased inputs was not collected, several dummy variables were generated from the qualitative information that was collected. The interpretation of these binary variables is simple: the coefficient in each variable measures the magnitude and effect of the variable on yields, holding everything else constant.

- <u>Use of seed from previous harvest</u>. Usually, farmers store part of their previous season's grain production to use as seed during the following season. If farmers' stored seed was affected by seed-borne diseases or stored under poor conditions (which will affect its quality), the use of seed from the previous crop could negatively affect yields. Although farmers were not asked questions regarding the quality of storage facilities, it is assumed they didn't store their seed under good conditions, which is very common among most small farmers. Farmers who used seed from the previous season were assigned a value of 1, while farmers who didn't were assigned a value of zero.
- <u>Diseases</u>. It is expected that as disease incidence increases, yields will decrease. Diseases include fungus and bacterial diseases such as rust, mildew, web blight, and bacterial blight, which are the most common diseases that affect beans. However, viral diseases are also included in this variable (e.g. bean golden yellow mosaic virus, bean common mosaic virus). Farmers were asked about the main factors negatively influencing yields and farmers who reported diseases as the main factor were assigned a value of 1, while farmers who didn't were assigned a value of zero.

- Drought. Drought periods may greatly affect yields, depending on the stage of the crop. For example, drought periods during the germination or flowering (early) stages will severely reduce yields, compared to drought periods in the pod-filling or ripening (late) stages. As droughts may have occurred in either of the two regions of the study, it is important to include a proxy for drought in the model. Farmers who reported drought as the main factor influencing yields were assigned a value of 1, while farmers who didn't were assigned a value of zero.
- Flooding. As with droughts, flooding can reduce yields and if severe, can cause total loss of the crop. Thus it is also important to include a proxy for flooding in the model. Farmers who reported flooding as the main factor influencing yields were assigned a value of 1, while farmers who didn't were assigned a value of zero.
- Lack of fertilizer. As is the case in many less developed countries, most Honduran farmers seldom apply purchased inputs, especially fertilizer. However, some farmers have the resources to purchase and apply small amounts of fertilizer and pesticides. It is expected that applying little or no fertilizer will negatively impact farmers' yields. This variable accounts for the no use of fertilizer during the season. As with diseases, drought and flooding, farmers who reported the lack of fertilizer as the main factor affecting yields were assigned a value of 1, while farmers who didn't were assigned a value of zero.

Socioeconomic characteristics

Although seven socioeconomic variables were initially included in the yield regression, after preliminary tests, two were excluded[73] from the analysis because of their low significance level (each variable had a p-value>0.6 and were jointly statistically non significant) and to increase the degrees of freedom, given the small sample size.

- Participation in agricultural projects prior to PPB. Approximately 36%[74] of sampled farmers reported they had participated in other agricultural projects prior to participating in the PPB project (excluding participation in the CIAL). From these farmers, 23% were still participating in some of these projects at the time of the interview. Therefore, it is expected that by participating in these projects farmers learned/are learning agricultural production techniques (not necessarily for beans) that they could apply to bean production (e.g. integrated pest management, manure use, crop rotation, etc.). This variable was included to control for farmers' prior knowledge of agricultural production techniques, which they acquired from other agriculture-related projects. Farmers who participated in agricultural projects prior to PPB or who are participating in other agricultural projects (non-CIAL projects) were assigned a value of 1, while farmers who didn't were assigned a value of zero.

- Age of household head. Age of household head (in years) can have diverse effects on yields. On one hand, the older the farmer, the more knowledge s/he has about bean

[73] Dependency ratio and number of adults with more than three years of education were excluded from the analysis. The dependency ratio was estimated by dividing the number of family members under 16 years plus the number of members older than 60 by the household size, following Bellemare and Barrett (2006).

[74] This percent is lower than the percent reported in Table 4.11 (i.e. 47%) because Table 4.11 is at the plot level, not at the household level.

production; hence, higher yields are possible. On the other hand, as farmers grew old the amount of physical work they can carry is diminished. Therefore, age could have a positive or negative impact on yields.

- Gender of household head. A common practice in the literature is to include gender of household head in the analysis. Sometimes, because female-headed households have less access to training, credit, and purchased inputs than male-headed households, they have lower yields than male-headed households. Male-headed households were assigned a value of 1, while female-headed households were assigned a value of zero.

- Education of household head. Farmers were asked how many years of formal education they had completed. One might expect that farmers with more formal education could have an advantage because educated farmers can (potentially) better inform themselves about agricultural techniques that could help them to increase their production. On the other hand, more educated farmers may switch from producing staple crops to producing other crops (e.g. high-value crops). However, given that the average education of the head was 3.3 years,[75] we expected this variable to have a small effect on yields.

- Hectares owned. The number of hectares owned could positively or negatively affect yields. The more hectares a farmer owns, the more resources s/he may have to invest in bean production. However, s/he could also decide to produce other (more profitable) crops and plant less beans (or neglect the crop). Because all of the respondents are bean-producing farmers, we expected this variable to have a positive effect on yields.

[75] See Table 4.1.

Access to financial resources

- Tropical livestock units (TLU). Using FAO conversion factors for Central America, the total number of TLU was estimated. One TLU equals 1.43 cattle, 1.25 horses, 4 pigs, 10 sheep, 1.43 mules, and 1.43 mares.[76] It is common that richer farmers have more livestock (and perhaps higher yields since they could buy inputs). In addition, farmers could use their animals as a buffer to financial needs: they sell them as needed. Therefore, we expected that yields would increase as the number of TLU increased.
- Remittances. In rural areas of Honduras, remittances are a very important source of income for small farmers who often have a relative living in the United States or in large cities of Honduras who sends them money. Remittances can have two effects on bean farmers. Farmers could use part of their remittances to purchase inputs to increase their bean production or they could decide to grow and purchase more inputs for other crops. Farmers were asked the amount of money received from relatives during the year. However, they were not asked how much of that money they spent on bean production. Therefore, a dummy variable was created using this information. Farmers who received remittances were assigned a value of 1, while farmers who didn't were assigned a value of zero. The dummy variable was used to avoid overestimating the effect of the amount received on yields (e.g. if they received $500 per year, it is very unlikely that they used all of the money in bean production, but is very likely that they used part of it on the crop).

[76] Tropical livestock units included cattle, horses, adult pigs, sheeps, mares and mules. The cattle conversion factor was used for mares and mules, since FAO does not report a conversion factor for these animals.

- Access to credit. Farmers were asked whether or not they had access to credit from any financial institution (e.g. banks, coops, farmers groups). Farmers who had access to credit were given a value of 1, while farmers who didn't were given a value of zero.

Quasi-fixed variables

- Season. Given that yields vary depending on the season, farmers who planted in the *Primera* season were given a value of zero, while farmers who planted beans in the *Postrera* season were given a value of one.
- Region. This dummy variable was created to control for rainfall effects. Communities in the Yoro department are located in a dry region, while communities in the Yojoa Lake region are in a wet region. Therefore, this variable helps to explain the yield difference between a dry versus a wet production region. Communities in the Yojoa Lake (wet) region were assigned a value of 1, while communities in the Yoro (dry) region were assigned a value of zero.
- Altitude (meters above sea level). Usually, for beans, the higher the elevation, the lower the yields. In Honduras, common beans are less productive in high altitudes because the high relative humidity combined with low temperature increase the incidence of seed-borne diseases such as anthracnose (Rosas, 2003c) and root rots. Additionally, in the tropics, beans do not grow well at low altitudes because of high temperature and pest incidence; therefore, medium to high altitudes are preferred. The altitude of the communities was used as a proxy for farm altitude because the farms were not visited. Communities were located at different altitudes, ranging from 750 to 1,650 m.a.s.l.

- Distance to main market (kilometers). This continuous variable was used as a proxy for transportation costs, since these costs will increase as the distance to the market increase. Similar to the variable altitude, given that the plots were not visited, this variable reflects the distance between the community and the main market. Taulabé was assumed to be the main market for communities located in the Yojoa Lake region, while Yorito was assumed to be the main market for communities located in the Yoro region.
- Interaction term of altitude and distance to main market. Given that both altitude and distance to market were collected at the community level (not at the farm level) and that, on average, communities closer to the market were located at higher altitudes[77] (where beans are expected to produce less because of lower temperatures and high disease incidence, see Table 2.1), it was necessary to control for the combined effect of these variables to avoid misleading results. Because of this, altitude multiplied by distance to market was included as an explanatory variable.

The Breusch-Pagan/Cook-Weisberg test for heteroskedasticity was performed to determine whether the variance was constant. The results of this test showed that the variances were not constant. Therefore, the *p-values* of the yield regression results were estimated using the robust (to heteroskedasticity) standard errors.

4.4.4.2 Empirical results

The yield regression was estimated at the variety level because some farmers planted more than one variety type in the same field. Therefore, although 148 farmers planted beans in the 2005 agricultural year (94 in the *Primera* season and 54 in the

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[77] Communities located above 1,000 m.a.s.l. (average of 1,415 m.a.s.l.) were 13 km away from the main market while communities located below 1,000 m.a.s.l. (average of 855 m.a.s.l.) were 8 km away from the main market.

Postrera season), the number of sample observations used for analysis was 193. In addition to this, yields that were higher than two standard deviations from the mean were excluded from the regression because it was very unlikely that farmers could obtain such high yields.[78] The summary statistics and regression results are shown in Tables 4.11 and 4.12, respectively.

On average, farmers produced 669 kg of beans per hectare planted, ranging from 15 kg/ha to 1,745 kg/ha (Table 4.11). This average was lower than the national average (1998-2006: 717 kg/ha) (FAOSTAT, 2010). In addition, the variability[79] of yields in the sample was higher than the variability of yields at the national level (63% vs 17%, respectively).

As mentioned before, adoption of CPB varieties was low and, on average, only 9% of the bean fields were planted to a CPB variety. In contrast, 36% of the bean fields were planted a PPB variety during the year and, as expected, participant farmers planted more fields to PPB varieties than non-participant farmers (1% significance level, SL) (Table 4.11).

The use of stored seed was common since farmers reported that close to one-half of their fields were planted using seed from the previous season. Many farmers reported production losses due to problems such as diseases (20% of fields affected) and flooding (27% of fields affected). In contrast, farmers reported that droughts (9% of fields) and

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[78] Yields higher than 1816 kg /ha were excluded (corresponding to 12 varieties). However, the number of farmers remained constant.

[79] Variability was measured by the coefficient of variation, which was obtained by dividing the standard deviation by the mean. From now on, variability refers to coefficient of variation, unless noted otherwise.

Table 4.11. Summary statistics of variables included in the linear regression estimation of bean yields, *Primera and Postrera* 2005 seasons, Yoro and Yojoa Lake regions, Honduras.

	Participants[1]		Non-participants			All farmers			
Explanatory Variables	**Mean**	**SD**	**Mean**	**SD**	**MT[3]**	**Mean**	**SD**	**Min.**	**Max.**
Dependent variable (yield, kg/ha)	669.8	426.56	666.4	407.44		668.5	418.07	15	1,745
Project-related Variables:									
Planted a CPB variety (0=Landrace, 1=CPB)	0.09	0.29	0.08	0.27		0.09	0.28	0	1
Planted a PPB variety (0=Landrace, 1=PPB)	0.44	0.50	0.25	0.44	***	0.36	0.48	0	1
Production-related Variables (0=no, 1=yes):									
Used seed from previous harvest	0.46	0.50	0.49	0.50		0.47	0.50	0	1
Diseases were main problem	0.23	0.42	0.16	0.37		0.20	0.40	0	1
Drought was main problem	0.12	0.33	0.05	0.22		0.09	0.29	0	1
Flooding was main problem	0.28	0.45	0.26	0.44		0.27	0.45	0	1
Lack of fertilizer was main problem	0.03	0.18	0.09	0.29	*	0.06	0.23	0	1
Socioeconomic Characteristics:									
Participated in other agricultural projects prior to PPB (0=no, 1=yes)	0.55	0.50	0.34	0.48	***	0.47	0.50	0	1
Age of head (years)	44.56	13.11	44.12	14.21		44.39	13.52	18	79
Gender of head (0=female, 1=male)	0.91	0.29	0.97	0.16	*	0.93	0.25	0	1
Education of head (years)	3.38	2.99	2.89	2.19		3.19	2.71	0	12
Hectares owned	3.21	7.97	1.28	1.69	**	2.45	6.35	0	60
Access to Financial Resources:									
No. of Tropical Livestock Units[2]	1.48	2.33	1.41	3.92		1.45	3.05	0	33
Received remittances (0=no, 1=yes)	0.20	0.40	0.29	0.46		0.23	0.42	0	1
Have access to credit (0=no, 1=yes)	0.86	0.35	0.53	0.50	***	0.73	0.44	0	1
Quasi-fixed Variables:									
Season (0=Primera, 1=Postrera)	0.43	0.50	0.36	0.48		0.40	0.49	0	1
Region (0=dry region, 1=wet region)	0.37	0.48	0.32	0.47		0.35	0.48	0	1
Altitude (masl)	1,121	295.58	1,035	256.95	**	1,087	283.42	750	1,650

Table 4.11 (cont'd).

Explanatory Variables	Participants[1] Mean	Participants[1] SD	Non-participants Mean	Non-participants SD	MT[3]	All farmers Mean	All farmers SD	All farmers Min.	All farmers Max.
Distance to main market (km)	10.81	6.11	11.58	6.03		11.11	6.08	6	27
Altitude * distance to main market	11,004	3,731	11,081	3,725		11,034	3,719	7,571	20,475
Number of sample observations	117		76			193			

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] Participation includes current and past CIAL members from CIALs that implemented PPB.

[2] TLUs calculated using FAO conversion tables.

[3] MT = t-test of mean difference of participants and non-participants; *significant at 10%, **significant at 5%, ***significant at 1%.

lack of fertilizer (6% of fields) affected only a few bean fields. However, lack of fertilizer was more common among non-participant farmers (10% SL) (Table 4.11).

Most of the socioeconomic characteristics and access to financial resources were explained in Table 4.1. Therefore, for most of these variables, no explanation is provided in this section. On average, farmers owned 2.45 hectares of land. However, participant farmers owned 2.5 times more land than non-participant farmers (5% SL) (Table 4.11).

Finally, most bean fields were planted in the *Primera* season (60% of the bean fields) and most fields were planted in the Yoro region (65% of fields).[80] The fields were located at an average altitude of 1,087 m.a.s.l. and participant farmers planted beans at higher altitudes, compared to non-participant farmers (5% SL). The average distance between the communities and the main commercial towns in each region was 11.1 km (Table 4.11).

From the 21 variables included in the yield regression estimation, eight had a statistically significant effect on yields (Table 4.12). The model had an adjusted R^2 value of 0.3627, which indicates that the regression model fits the data well. Among the project-level variables, participating in the PPB project had no statistically significant effect on yields. In contrast, both planting a CPB and a PPB variety had a significant (positive) effect on yields, compared to planting a traditional variety. On average, farmers who planted a CPB variety obtained 359 kg/ha more beans than farmers who planted a

[80] Only a few farmers planted beans in the Yojoa Lake region in the *Postrera* season because excess rainfall is common in this region.

Table 4.12. Linear regression results of bean yields of small red varieties, *Primera* and *Postrera* 2005 seasons, Yoro and Yojoa Lake regions, Honduras (*n*=193).

Explanatory Variables	Yield kg / ha	p-value[3]
Project-related Variables:		
Participated in PPB (0=no, 1=yes)[1]	-4.75	0.927
Planted a CPB variety (0=Landrace, 1=CPB)	358.58	***0.001
Planted a PPB variety (0=Landrace, 1=PPB)	134.97	**0.020
Production-related Variables:		
Used seed from previous harvest (0=no, 1=yes)	82.75	0.137
Diseases were main problem (0=no, 1=yes)	-106.99	0.163
Drought was main problem (0=no, 1=yes)	-82.18	0.383
Flooding was main problem (0=no, 1=yes)	-182.17	***0.007
Lack of fertilizer was main problem (0=no, 1=yes)	-334.30	***0.001
Socioeconomic Characteristics:		
Participated in other agricultural projects prior to PPB (0=no, 1=yes)	86.66	0.117
Age of head (years)	-1.58	0.506
Gender of head (0=female, 1=male)	91.55	0.348
Education of head (years)	-15.39	0.124
Hectares owned	-8.42	*0.074
Access to Financial Resources:		
No. of Tropical Livestock Units[2]	36.04	***0.000
Received remittances (0=no, 1=yes)	57.52	0.363
Have access to credit (0=no, 1=yes)	45.86	0.489
Quasi-fixed Variables:		
Season (0=Primera, 1=Postrera)	-174.30	***0.002
Region (0=dry region, 1=wet region)	231.92	***0.004
Altitude (masl)	-0.06	0.807
Distance to main market (km)	22.77	0.412
Altitude * distance to main market	-0.01	0.805
Constant	465.79	0.113
Adjusted R-squared	0.3627	
F(21, 171)	10.25	
Prob > F	0.0000	

Source: B/C CRSP Survey of PPB project in Honduras, 2006.
[1] Participation includes current and past CIAL members from CIALs that implemented PPB; [2] Tropical Livestock Units calculated using FAO conversion tables;
[3] *** significant at 1%; ** significant at 5%; * significant at 10%; robust (to heteroskedasticity) standard errors used to estimate p-values.

traditional variety. Similarly, farmers who planted a PPB variety obtained an average of 135 kg/ha more beans than farmers planting a traditional variety.[81]

Despite the extremely high difference (359 kg/ha) in yields between CPB and traditional varieties, the economic impact of CPB varieties in these communities (increased yields times area planted) was lower than that of PPB varieties because only 4.0 hectares (i.e. 4.0% of the bean area) were planted to CPB varieties, compared to 31.1 has (or 31.6% of the bean area) planted to PPB varieties. Hence, in these communities, the economic impact of PPB varieties was 192% greater[82] than that of CPB varieties.

The results also suggest that CPB varieties are not poorly adapted to marginal environments (at least not the marginal environments evaluated in this study) as PPB advocates argue, since they yielded more than traditional (and PPB) varieties. However, the fact that adoption of CPB varieties was very low — despite their high yield — suggests that yield was not the only characteristic of importance to farmers. In addition to high yields, in deciding whether or not to plant a variety, farmers consider market value, cooking quality, plant architecture, and earliness. Farmers considered these characteristics of PPB varieties superior to those of CPB varieties (Table A.5). Furthermore, given both the low number of farmers planting CPB varieties and the low number of hectares planted to CPB varieties (in both seasons), the estimate of the yield of CPB varieties should be taken with caution.

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[81] Using farm trail data, Humphries *et al.* (2005) reported that the PPB variety *Macuzalito* yielded 387 kg/ha more than traditional varieties in the Yoro region.

[82] % increase = [(135 kg/ha * 31.1 ha) / (359 kg/ha * 4.0 ha) – 1] *100 = 192%

Although only a small percentage (6%, Table 4.11) of the farmers reported the lack of fertilizer as the main limitation in production, the effect of this variable on yields was large, negative, and statistically significant (1% SL). Farmers reporting a lack of fertilizer as the main production constraint obtained, on average, 334 kg/ha less than farmers who didn't report this as their main production problem. Furthermore, flooding had a large, negative, and statistically significant (1% SL) effect on yields. This was expected since excess rainfall causes flooding, among other problems (e.g. loss of soil, landslides, etc.), which reduce yields significantly. Farmers reporting flooding as their main production problem obtained, on average, 182 kg/ha less than farmers who didn't report this problem during this cropping season (Table 4.12).

Table 4.12 also shows that farmers who had participated or who were participating in other agricultural projects (excluding the CIAL) obtained, on average, 87 kg/ha higher bean yields. Although not statistically significant, this variable was very close to becoming significant at the 10% level. Farmers who reported participating in other projects said they participated, on average, in 1.44 projects, which focused on crop-related training (mainly for staple crops) and natural resources management.

As the number of hectares owned increased, yields decreased. Although farmers who owned more land obtained lower yields (10% SL), the size of this effect was small (for every additional hectare, yields decreased by 8.4 kg) (Table 4.12). This negative effect could have happened because farmers who have more land may use the best land to grow other (high-value) crops, planting beans in less productive sections of their farms. In addition, these farmers may devote more effort to their other (high-value) crops, hence putting less effort on bean production. However, since information about other crops was not collected, it is not possible to confirm this.

As expected, farmers with more access to financial resources had higher bean yields. For every additional tropical livestock unit farmers owned, bean yields increased by 36 kg/ha (1% SL) (Table 4.12). Farmers who have more TLU usually are wealthier farmers who could purchase inputs and could also use manure (from these animals) in their fields, which help to increase yields.

Farmers who produced beans in the *Postrera* season obtained, on average, 174 kg/ha less than farmers producing beans in the *Primera* season. This result suggests that, in these communities, the *Primera* may be a better season to produce beans. Most of the area planted to beans was planted in the *Primera* season (62.4 has vs. 36 has in the *Postrera*, see Table 4.8); however, the average area planted per farmer was almost the same in both seasons.[83]

Finally, farmers located in the wet (Yojoa Lake) region produced, on average, 232 kg/ha more (1% SL) than farmers producing in the dry (Yoro) region.

4.5 Do the benefits outweigh the costs to farmers? An Economic Analysis using Net Present Value and Internal Rate of Return estimations

To evaluate the economic benefits of the PPB project, both Net Present Value (NPV) and Internal Rate of Return (IRR) methodologies were used. Belli *et al*. (2001) provide detailed information about the considerations needed when estimating NPV and

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[83] The average area planted to beans was 0.66 hectares in the *Primera* season and 0.67 hectares in the *Postrera* season. This difference was not statistically significant.

IRR, which were followed in this analysis. The NPV and IRR were estimated using a "with" and "without" PPB-project scenario. Under the "with" project scenario, it is assumed that farmers will plant PPB varieties generated by their community's CIAL; obtaining higher yields compared to traditional varieties.[84] Under the "without" project scenario, it is assumed that farmers will plant traditional varieties because PPB varieties (and CPB varieties with characteristics preferred by farmers) are not available. Therefore, the benefit-cost analysis conducted in this study is structured not to determine the profitability of PPB relative to CPB, but rather to determine the profitability of PPB for farmers in niche environments who would not otherwise adopt improved CPB varieties.

Additionally, it is assumed that there is a CIAL in the communities "without" the PPB project (i.e. the CIAL will do research in activities other than PPB).[85] The implication of this is that in the benefit-cost analysis, the annual cost of maintaining a CIAL are excluded from the estimations since both "with" and "without" project scenarios have a CIAL (however, only in the "with" project scenario farmers have access to PPB varieties). Finally, the analysis does not take into account investments made in technical assistance by NGOs and Zamorano. Although this underestimates our costs

[84] In principle, farmers could plant CPB varieties instead of PPB varieties. However, the data suggest that adoption of CPB varieties has been low. Therefore, it is assumed that farmers will choose between traditional and PPB varieties only.

[85] This is a valid assumption because it would not be expected to start a CIAL only to implement PPB. Instead, it is expected that PPB will be added as an activity in established CIALs.

(because including PPB as an additional CIAL activity has a cost to the institutions providing assistance to farmers), it is assumed that these costs are small.[86]

A sensitivity analysis was done to key parameters to test the effect of variations in these variables to the profitability of the PPB project. Table 4.13 summarizes the assumptions made under each scenario and Table 4.14 summarizes the results from NPV and IRR estimations for each scenario.

4.5.1 Assumptions made to estimate NPV and IRR

For all scenarios, the following general assumptions were made:

(a) Together, the nine CIALs released a total of five PPB varieties in the fifth year after starting the breeding process.[87] Adoption is assumed to follow the logistic adoption curve described in section 4.4.3 (see Table A.9 for details). Given that farmers only need starter seed (since they could plant good-quality grain from their harvest), it is assumed that after the variety is released, the CIALs will not continue doing PPB-related activities. Furthermore, since registering the varieties doesn't give farmers any additional benefits,[88] the costs of the paperwork (for registration) were excluded from the analysis.

(b) It is assumed that the PPB variety will be used for 16 years after it is released. This assumption was made based on two reasons: (1) *Dorado*, one of the most widely adopted CPB varieties, reached its maximum adoption rate 11 years after it was released

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[86] The per unit cost will decrease if the same facilitator provides PPB assistance to a higher number of CIALs.

[87] The process to release *Macuzalito* took five years, from 2000 (when the crosses were made) to 2004 (when the variety was released).

[88] Despite registration, the seed of PPB varieties can't be sold as certified seed because these varieties were developed for niche environments. Therefore, PPB varieties are registered mainly to give recognition to the farmers that developed them; hence, adding no quantifiable benefits.

(Mather *et al*., 2003) and is still planted in some regions of the country (although only a small area is planted to this variety). Similarly, the same authors estimated that *Tío Canela 75* (released in 1996) would reach its maximum adoption level in 2007, 11 years after it was released and will be used beyond 2010 (a fact since *Tío Canela 75* is still widely used throughout the country). (2) Given the difficulty of generating new (PPB) varieties, it is not expected that new PPB varieties would replace current ones in a short period of time.

(c) Farmers would receive an average bean farm gate price of \$0.66 kg^{-1} of beans. This price was estimated by averaging the SIMPAH[89] 2005 wholesale price data for the months of May to December because this period includes both cropping seasons (SIMPAH, 2007). Given that the prices reported by SIMPAH are at the wholesale level (i.e. they reflect the price of beans in the main cities of the country), they were adjusted to reflect the farm gate price. For this, it was assumed that the wholesale price had a 10% marketing margin above the farm gate price.[90] Additionally, it was assumed that bean prices remain constant over time, remaining at the 2005 estimated price.

(d) Following Mather *et al.* (2003), it was assumed that farmers will not achieve any costs savings (labor and input) from planting PPB varieties, although it is possible that farmers who plant resistant varieties could save some of these costs from reduced pesticide applications.

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[89] SIMPAH is the Honduran Agricultural Price Information System.

[90] The average SIMPAH wholesale price was divided by 1.10 to reflect the farm-gate price. One local broker commented he would charge 10% of the value of beans to move them from the Yojoa Lake region to Puerto Cortez, which is the best estimation available for transportation costs. It was assumed a marketing margin of 10% based on this information.

(e) During the five years required to develop the PPB variety, an average of nine farmers will work in the CIAL that will develop the variety.[91]

(f) The CIAL farmers will attend 24 meetings through the year (CIAL members reported holding two meetings per month, each of 2-3 hours average), for years one to five. We will assume (for simplicity) that each meeting is four hours (half day) long; therefore, they would spend twelve (8 hr) days per year in meetings. However, given that these meetings are used to discuss issues related to all activities carried by the CIAL (as reported by respondent farmers), this number was divided by 2.8, the average number of activities carried by the sample CIALs, to reflect the time devoted to PPB activities (i.e. 4.3 days).

(g) Additionally, farmers reported working, on average, 10 days in field activities related to PPB during the year. However, it is expected that during the first years, farmers will work less on the field since most of the fieldwork is done in late stages of the process. Therefore, it was assumed that farmers worked only 5 days in the first year, 8 days in the second year, and 10 days in years 3-5. After year six, it is assumed that farmers will not work on PPB-related activities.

(h) The opportunity cost of labor was estimated at \$2.32 day^{-1}, which was obtained by averaging the daily wage across all communities in the study, that is, the market wage rate. This opportunity cost was used to obtain a monetary value to the opportunity cost of farmers working on PPB-related activities through the year.

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[91] At the time of the study (2006), there were 35 CIALs with a total number of 347 members in the Yoro region (average of 9.9 people per CIAL) and 12 CIALs with a total of 104 members in the Yojoa Lake region (average of 8.7 people per CIAL). In our sample, the average number of people per CIAL was 8.6 in Yoro and 8.75 in the Yojoa Lake region.

(i) It is assumed that all communities have a CIAL. However, only under the "with" project scenario will CIALs do PPB activities. Therefore, the results of the economic analysis will indicate whether or not a CIAL should add PPB as an additional activity. The cost of facilitating and maintaining a CIAL was estimated at $670 for the first year but this cost averages $325 per year for years one to six (Ashby *et al*. 2000). However, we assume these as sunk costs and the incremental cost of the PPB project to the CIAL are given by the cost of the breeding lines (excluding paperwork costs -- see Table 4.3 and Table A.3 for details) plus the cost of the time farmers spent on PPB activities (i.e. meetings and fieldwork; see (f) and (g) above for details).

(j) The PPB breeding costs shown in Table 4.3 and detailed in Table A.3 were adjusted to reflect the breeding materials (or lines) used in years 1-4, and the number of varieties released in year five. Although nine CIALs worked on PPB activities, only six sets of breeding lines were used for years one to four. As reported by Humphries *et al.* (2005) *Macuzalito* was developed by four CIALs who used a single set of breeding lines. For all other PPB varieties, each CIAL used its own unique set of breeding lines. Additionally, since only five varieties were released in year five, the costs of breeding materials in year five took this into account (i.e. total costs for year five were multiplied by five, not six). Additionally, it is assumed that after year five, no PPB-related activities will be done.

(k) Lastly, the discount rate is assumed to be 10%, which is the same discount rate used by Mather *et al*. (2003) to estimate the economic impact of disease-resistant bean varieties in Honduras. High discount rates are commonly used to evaluate the economic impact of projects in developing countries (AEC 865, 2008). The Central Bank of

Honduras (BCH, 2010a, 2010b) reported an average annual interest rate of 18.83% for loans in local currency and 8.625% for loans in foreign currency for the year 2005. Therefore, a 10% discount rate seems reasonable since our estimations are made in foreign currency.

One limitation of the analysis is that it does not account for investments made in technical assistance provided by NGOs and Zamorano.[92] These organizations trained farmers on PPB and assisted them through the implementation process. However, although this omission overestimates the NPV, it is expected not to seriously bias the results since the organizations' technicians usually provide training for all activities carried by the CIAL (not only PPB) and one (or two) technician(s) visit many CIALs (not only the ones doing PPB). Therefore, the real cost of their time spent on PPB-related activities is likely modest.

For the sensitivity analysis, the following three scenarios were evaluated (Table 4.13):

Scenario A. This is the base scenario, which used the empirical results from sections 4.4.3 and 4.4.4 about adoption rates and yield differences (between traditional and PPB varieties). Therefore, it is assumed that PPB varieties yielded 135 kg/ha more than traditional varieties. For each year, the area planted to PPB varieties equals the percentage of adoption from the logistic curve (Table A.9) times the total bean area (i.e. 98.4 has). By year 2008, the maximum adoption rate (52%) and hectares (51 ha) was reached.

[92] Cost information about these activities was not collected.

Table 4.13. Assumptions made for the sensitivity analysis of NPV and IRR estimations of the PPB project, Honduras, 2006.[1]

	Scenarios[5]		
Variables	**A (base)**[6]	**B**	**C**
Average yields (kg/ha):			
(1) Traditional variety	669	669	669
(2) PPB variety	804	**872**	804
Yield difference [(2)-(1)]	135	**203**	135
Production cost increase ($/ha)[2]	0	**35**	0
PPB adoption ceiling	52	52	**59**
No. of sets of breeding lines used, years 1-4 [3]	6	6	6
No. of CIALs working on PPB, years 1-5	9	9	9
No. PPB varieties released	5	5	5
No. of years needed to release a variety	5	5	5
Variety's life cycle (years)	16	16	16
Average bean farm gate price ($/kg)	0.66	0.66	0.66
No. farmers per CIAL	9	9	9
No. CIAL meetings, years 1-5 (days/year)	12	12	12
No. meetings to PPB (days/year)[4]	4.3	4.3	4.3
No. days worked in field, year 1	5	5	5
No. days worked in field, year 2	8	8	8
No. days worked in field, years 3-5	10	10	10
Opportunity cost of labor ($/day)	2.32	2.32	2.32
Discount rate (%)	10	10	10

[1] NPV = Net Present Value; IRR = Internal Rate of Return; PPB = Participatory Plant Breeding.

[2] Assumes a per unit production cost of $0.513/kg (estimated from Tshering 2002). However, this cost is applied to the difference in yield increase from Scenario A to Scenario B; i.e. to 68 kg/ha.

[3] In year five, for all scenarios, five sets of breeding lines were used since five varieties were released.

[4] These values were obtained by dividing the total number of meetings by 2.8, the average number of activities carried by each CIAL, to reflect the share devoted to PPB activities.

[5] Bold shows changes in key variables with respect to the base scenario.

[6] This scenario uses the empirical results from sections 4.4.3 and 4.4.4.

Although nine CIALs were working on PPB activities, only five varieties were released. Therefore, the cost of breeding materials in year five were multiplied by five (see (j) above for details) and after year five, no PPB-related activities will be carried out. Furthermore, it is also assumed that there will be no incremental production costs from planting PPB varieties.

Scenario B. Under this scenario, it is assumed that the yield difference between PPB and traditional varieties will be 50% higher than for *Scenario A* (i.e. 203 kg/ha)[93] and that bean production costs will increase because additional labor will be needed, especially during harvesting. All other variables are assumed to be the same as in *Scenario A* above.

This 50% yield increase may be possible for two reasons. (1) The regression results suggest that CPB varieties yielded, on average, 359 kg/ha more than traditional varieties; and (2) Humphries *et al*. (2005) reported that, in the Yoro region, *Macuzalito* yielded 387 kg/ha more than traditional varieties (average across three communities).[94] Both reasons suggest that higher yields are possible.

Tshering (2002, pgs 50 & 61) estimated that bean production costs were $234/ha in the *Primera* and $218/ha in the *Postrera* (averaging $226/ha). On average, 33% of production costs in the *Primera* and 25% of production costs in the *Postrera* were related to cost of inputs (i.e. fertilizer, pesticides), hiring traction, and equity capital. It is assumed that these costs will remain constant because higher yields (from PPB varieties)

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[93] In Scenario A, the yield difference between PPB and traditional varieties was 135 kg/ha. A 50% increase in this difference equals (135 kg/ha* 0.50) + 135 kg/ha = 68 kg/ha + 135 kg/ha = 203 kg/ha.

[94] These communities are three of the five communities evaluated in the present study.

will mostly increase the labor required during the crop cycle; therefore, incremental costs only reflect increased (family and/or hired) labor costs. Tshering (2002) estimated that his sampled farmers obtained an average yield of 276 kg/ha in the *Primera* and 356 kg/ha in the *Postrera*.[95] Using the above information, it was estimated that per unit costs were \$0.567 kg^{-1} in the *Primera* and \$0.459 kg^{-1} in the *Postrera*, which gives an average of \$0.513 kg^{-1}. Given that Tshering's yields were so low, this unitary cost may be overestimated. Thus, in this scenario, the incremental cost per hectare was estimated by multiplying Tshering's unitary cost (i.e. \$0.513 kg^{-1}) times the difference in yield increase between *Scenarios B* and *A* (i.e. to 68 kg/ha). Therefore, the increase in production cost is \$35/ha.

Scenario C. Under this scenario, it is assumed that the yield difference between PPB and traditional varieties and bean production costs will be the same as under *Scenario A* (i.e. 135 kg/ha and there will be no incremental production costs). However, it is assumed that the (PPB) adoption ceiling will be higher.[96] The average adoption rate among three of the four communities that developed *Macuzalito* was 59% (excluding the community with the lowest adoption rate). Therefore, in this scenario, it is assumed that adoption ceiling will be 59% (up from 52% in *Scenarios A* and *B*). All other variables are assumed to remain constant.

Increasing the adoption ceiling of PPB varieties to 59% increases the parameters in the logistic curve to α=-6.1620 and β=2.1015. Using these new parameters plus the

[95] These yields seem extremely low, even for the Yoro (dry) region.
[96] In order to reach this new adoption ceiling, effort needs to be devoted to promote the use of PPB varieties. These costs are not included in this.

adoption rate at the time of the study and the new adoption ceiling, new adoption rates can be estimated for every year. Assuming the year of release as year one, adoption rate becomes 7.3% in year two, it remains the same as in *Scenarios A* and *B* (at 31.6%) in year three,[97] increases to 53.3% in year four, 58.2% in year five, 58.9% in year six, and 59% from years seven to 16. Therefore, the maximum adoption ceiling will be reached seven years after the varieties are released (contrary to six years in all other scenarios).

4.5.2 Results of NPV and IRR estimations under proposed scenarios

Scenario A. The economic NPV analysis for the base scenario (*Scenario A*, which uses the empirical results) shows that investments in the PPB project have been profitable (NPV=$969) in the way it was implemented (Tables 4.14 and A.10). However, the project would become unprofitable (i.e. NPV<0) if the discount rate is above 10.73% (IRR), which is very close to the discount rate used for our estimations.

Although profitable, the present value of the net benefits of PPB is very low due to several reasons. *First*, probably the most important reason is that the yield difference between PPB and traditional varieties was small. Therefore, the economic benefits of PPB per hectare were small (see *Scenario B* for estimations with higher yield differences). *Second*, too many CIALs were doing PPB activities,[98] which increased the total investment on PPB per year, particularly for year five. In year five, costs increase because many activities must be done to be able to release the bean variety chosen (e.g.

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[97] Adoption rate is the same in year three because this is the adoption rate at the time of the study (which is the same in *Scenarios A* and *C*).

[98] Nine CIALs were doing participatory breeding during the period of evaluation. However, only five varieties were released and adoption was relatively low compared to the number of varieties released and the number of CIALs doing participatory breeding.

Table 4.14. Summary of results of the NPV and IRR estimations of the PPB project, Honduras, 2006.[1]

Items	Scenarios[3] A (base)[4]	B	C
Key variables:			
Average yields (kg/ha):			
(1) Traditional variety	669	669	669
(2) PPB variety	804	**872**	804
Yield difference [(2)-(1)]	135	**203**	135
Production cost increase ($/ha)	0	**35**	0
PPB adoption ceiling	52	52	**59**
Net Present Value ($)[2]	969	3,001	3,073
Internal Rate of Return (%)	10.73	12.14	12.17

Source: Estimations made by The Author.

[1] NPV = Net Present Value; IRR = Internal Rate of Return; PPB = Participatory Plant Breeding.

[2] Assumes 10% discount rate.

[3] Bold shows changes in key variables with respect to the base scenario.

[4] This scenario uses the empirical results from sections 4.4.3 and 4.4.4.

planting the demonstrative field). In the estimations, if the number of CIALs working on PPB from the beginning of the process is reduced from nine to five (holding all other variables constant), the NPV becomes $4,979 and the IRR is 14.48% (estimations not shown), which looks more attractive to both farmers and donors.[99]

Third, the area planted to PPB varieties was not very large (i.e. only 32 ha at the time of the study). One limitation of the study is that adoption data from other nearby

[99] However, these estimations don't account for the potential increase in PPB cost (e.g. NGOs and Zamorano may need to increase their technical assistance to CIALs to be able to release the same number of varieties with fewer CIALs) and assumes that fewer CIALs will be able to produce the same output, which may not be the case.

communities was not collected. Therefore, it may be possible that adoption is underestimated, since farmers in nearby communities could have planted some of these PPB varieties. In addition, non-monetary benefits (e.g. higher knowledge, increased women participation, etc.) are not included in the NPV estimation, which certainly underestimates the total benefits of PPB. Hence, the benefits could be larger (see *Scenario C* for estimations with higher adoption levels).[100]

<u>*Scenario B*</u>. Compared to *Scenario A*, if the yield difference between PPB and traditional varieties is 50% larger and production costs increase by $35/ha, holding everything else constant, the NPV of the project becomes $3,001 and the IRR is 12.14% (Tables 4.14 and A.11). That is, investing in PPB is profitable until the discount rate increases to 12.14%, after which, the NPV of the project will become negative and stakeholders should invest in alternative (profitable) projects.

This scenario is much more attractive than the base scenario and, it may be possible to realize it in at least two ways: (1) future PPB projects could breed bean varieties that yield more than current ones; and (2) NGOs and Zamorano could promote better production techniques or could help to mitigate production constraints (e.g. increasing credit availability so farmers can purchase inputs) which may help to increase yields, using current PPB varieties. The disadvantage of these two solutions is that both will drive PPB costs up and new PPB and IRR estimations would be necessary to confirm the benefits of these actions.

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[100] Although this is true, as mentioned in Section 4.4.3, adoption of PPB varieties in other communities may not be very high and more work should be devoted to promoting these varieties in other communities to increase adoption.

Scenario C. Compared to *Scenario A*, if the adoption ceiling increases to 59% and all other variables are held constant,[101] the NPV of the PPB project becomes \$3,073 and the IRR is 12.17% (Tables 4.14 and A.12). If the discount rate increases to more than 12.17%, investing in PPB becomes unprofitable and it would be better for farmers and donors to invest in alternative (profitable) projects.

Increasing the area planted to PPB varieties would require promoting the varieties within and in other communities and convincing neighbors about the benefits of these varieties so they adopt them. If the costs related to promoting activities were higher than \$3,073, the PPB project would become unprofitable (i.e. NPV<0). One way to keep promotion costs low is by promoting PPB varieties through CIAL members in neighboring communities; that is, through CIAL members in communities that don't have PPB projects.[102] This strategy would enable both CIAL and non-CIAL members in these communities to learn about PPB varieties and adopt them.

4.5.3 Should PPB be "scaled up" to other regions of Honduras?

The answer to this question is "yes," the PPB project should be implemented by CIALs in other regions of Honduras since the net present value of the investments made in PPB is greater than zero. However, this is true if the costs and benefits remain in the same proportion as the project is scaled up. If costs go up more rapidly than benefits as the project is expanded, then the PPB project may not maintain its profitability. For example, to scale up PPB, NGOs may need to hire additional technicians to provide

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[101] One strong assumption is that production costs will remain constant when planting PPB varieties.

[102] In principle, this may not be difficult since all CIAL members know each other. Therefore, there are economies of reputation that could be exploided to reach this goal.

technical assistance to farmers. If the cost of added staff is larger than the benefits, then PPB will not be profitable.

Several factors should be considered if the PPB initiative is to be scaled up. *First*, given that the project's NPV was very close to zero, stakeholders should carefully consider how many CIALs are needed to implement PPB, since this greatly affects the profitability of the project. *Second*, careful thought should be given to selecting CIALs with different environmental conditions than the CIALs that have already released PPB varieties.[103] *Third*, although the results show that the socioeconomic differences between PPB and non-PPB farmers were small, it is important that farmers who will implement PPB in the future receive previous training in research methodologies.[104] As mentioned by Humphries *et al*. (2005), for a PPB initiative to be successful, the farmers must have received previous training in formal research methods (e.g. trial management, PVS, production techniques, etc).

Fourth, future PPB varieties should have a higher yield advantage (compared to traditional varieties) than current ones. The sensitivity analysis showed that, if the yield difference between PPB and traditional varieties were 50% higher (i.e. if yield difference goes up from 135 kg/ha to 203 kg/ha), the profitability of PPB could be at least three times higher. *Finally*, more work should be devoted to promote the use of PPB varieties so more farmers adopt them and the benefits will be larger.

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[103] Communities with similar environmental conditions should test (existing) released PPB varieties for adaptation to their conditions (a very advanced PVS methodology because only one variety will be tested), instead of developing a new variety.

[104] This may not be a problem since most CIAL members have received this type of training.

4.5.4 Is PPB self-sufficient in the long run?

One specific objective of this study was to determine whether the PPB project is self-sufficient in the long run. Although sufficiency is a general word that mean different things to different people, in this study, it refers to whether the PPB projects would be able to continue their activities, if the NGOs and/or Zamorano stop their collaboration. At the time of the study, the PPB projects depended on Zamorano's breeding program to produce the materials used in the breeding process and also depended on Zamorano and NGOs for financial and technical support.

Zamorano has either provided lines from (a) its own crosses (i.e. from crosses that may not use landraces as parents) or (b) from crossing local varieties (as requested by some CIALs) with promissory lines or even CPB varieties, which farmers have used to generate PPB varieties. Given that few farmers know how to make bean crosses (80% of PPB farmers didn't know how to make bean crosses and only 9%--or five out of 55 farmers--knew very well how to make crosses) and that making crosses is both expensive and difficult, PPB projects will continue to depend on Zamorano's breeding program to obtain segregating lines.

This may not be a major constraint, since many of the varietal development programs based at national agricultural research systems in other Central American countries (including Honduras) also depend on Zamorano's (and CIAT's) breeding program to obtain segregating lines. Additionally, it may not be cost effective for farmers to do this activity since, as mentioned above, is very expensive and requires comprehensive knowledge about the breeding process.

Furthermore, farmers suggested they need increased support (both financial and technical) from Zamorano and the NGOs to continue their activities (see Table 4.2 for details). For all of these reasons, the PPB projects will continue to dependent on assistance from these organizations.

4.6 Chapter summary

The descriptive analysis showed that the socioeconomic differences between participants and non-participants were not statistically significant (and minimal) for most variables. However, there were several (statistically significant) differences between farmers of Yoro and Yojoa Lake regions (e.g. household size, access to credit, number of tropical livestock units, etc.).

Stakeholders reported several strengths and weaknesses of the PPB project. Farmers reported their expectations from participating in the project have been met. A clear strength of the project was its reputation--farmers perceived the PPB project was good because Zamorano, FIPAH, and PRR were the organizations that implemented it. Because the farmers previously worked with these organizations, they had confidence in them.

Regarding weaknesses of the PPB project, while most farmers were satisfied with the work done by the organizations, farmers in the Yojoa Lake region were more satisfied with both Zamorano's and PRR's role in the project than farmers in Yoro. This was because in Yoro, FIPAH was assisting a larger number of CIALs, compared to PRR in the Yojoa Lake region. Clearly, additional resources are necessary to enhance the organization's capacities to better meet farmers' needs. Another weakness reported by farmers was their (technological and financial) dependence on Zamorano and the NGOs to continue with the project. Finally, one third of non-participant farmers were not aware of the CIAL's work.

Zamorano's breeder mentioned that some of the strengths of the project were that it reduced the time required for adoption of bean varieties, and increased both the effectiveness of the trials and the probability of adoption of PPB varieties. Among the weaknesses, he mentioned the need to scale up PPB to other regions in order to have widespread impact and its dependence on CPB to succeed.

NGOs' staff mentioned that some of the strengths of PPB were that it increased farmers' capacity to conduct research and implement the participatory-based methodology of PPB. Among the weaknesses, they included the need for additional funding and PPB's dependence on CPB.

The results show that the cost to develop a bean variety through PPB is 20% of what it cost to develop a variety at an experimental station. However, these cost reflect the nature of the PPB process itself, for which the main objective is to develop varieties for niche environments, hence requiring less resources.

Both non-economic and economic benefits were identified. Using a knowledge scale, it was found that PPB farmers had a clear knowledge of the process needed to develop bean varieties. There were statistically significant differences in PPB knowledge (as expected) between PPB participants and non-participants. However, among participants, there were no statistically significant differences between regions.

Many farmers had traded PPB varieties at some point in time. As expected, trade was affected by participation in the project (more participant farmers traded these varieties) and by region (trade in the Yoro region was higher than in the Yojoa Lake region). The results also suggest that there appears to be a slightly more developed seed market in the communities of the Yoro region because more farmers in this region reported purchasing seed. However, given the low percentage of farmers who purchased seed, this finding should be used cautiously.

As expected, traditional varieties were planted most widely, followed by PPB varieties and, far behind, by CPB varieties. *Macuzalito* was the most widely-adopted PPB variety, while *Tío Canela 75* was the most widely adopted CPB variety. However, the number of hectares planted to *Tío Canela 75* was only 11% of the number of hectares planted to *Macuzalito*. Low adoption of CPB varieties was expected, since the PPB projects were implemented in communities that had low adoption levels of CPB varieties. Furthermore, the PPB adoption curve showed that PPB varieties could reach their adoption ceiling in a short period of time (i.e. 6 years after release).

Among the economic benefits, the main finding was that both PPB and CPB varieties yielded more than traditional varieties. Farmers who planted a PPB variety obtained an average yield that was 135 kg/ha greater than farmers planting a traditional variety. Additionally, CPB varieties yielded 358 kg/ha more than traditional varieties. Despite the extremely high difference in yields between CPB and traditional varieties, the economic impact of PPB varieties in these communities was 192% larger than that of CPB varieties (mainly due to the differences in area planted to these varieties). These results also suggest that CPB varieties may perform better than expected in these niche environments. However, yield was not the only characteristic of importance to farmers since adoption of CPB varieties was very low, despite their high yield.

The NPV analysis showed that investments in the PPB project were profitable. However, the project bordered on becoming unprofitable (i.e. NPV<0) because the IRR was very close to the discount rate used for the NPV estimations. The sensitivity analysis indicated that the project may become more profitable if additional investments are made to (a) increase the yield of current and future PPB varieties (assuming the process will continue) or (b) additional efforts are devoted to promote the use of PPB varieties and thereby increase adoption rates. To implemented PPB with other CIALs in other regions of Honduras, stakeholders should: *first* carefully consider how many CIALs are required to implement PPB; *second*, select CIALs with different environmental conditions than the CIALs that have already released PPB varieties; *third*, select farmers who have received previous training in research methodologies; *fourth*, develop PPB varieties with higher yield advantage (compared to traditional varieties) than current ones; and *finally*, increase efforts to promote the use of PPB varieties.

Finally, regarding self-sufficiency, the PPB projects will continue to depend on Zamorano's breeding program to obtain segregating lines to start the breeding process and on Zamorano and NGOs for financial and technical support.

CHAPTER 5. SUMMARY, IMPLICATIONS, LIMITATIONS OF THE STUDY, AND FUTURE RESEARCH

This chapter summarizes the thesis and highlights the implications of these results for PPB stakeholders. Additionally, it points out the limitations of the study and suggests areas for conducting future research.

5.1 Summary

Common beans are Honduras' second most important basic grain crop after maize. As in all countries in Central America, the Honduran diet is based mainly on corn and beans, the major source of protein for poor households. During the past decades, bean breeders have developed several improved varieties (IVs) to address biotic and abiotic stresses that reduce yields. While studies indicate that these varieties are planted by 41-46% of Honduras' bean farmers, many small farmers, especially farmers producing in marginal areas, have not adopted them. It is estimated that small farmers account for about 40% of Honduras' total bean production. Thus, if more farmers adopted IVs, the impact would be substantial. Agricultural scientists have identified participatory plant breeding (PPB) as a strategy for increasing adoption and thereby extending the benefits of IVs to more farmers.

This study (1) examines the strengths and weaknesses of PPB projects in two regions of Honduras; (2) estimates the benefits and costs of PPB to farmers; and (3) generates recommendations for successfully scaling up the PPB methodology to include more regions of the country.

The study was conducted in two regions of Honduras, which included the departments of Yoro (first region, called Yoro region), and Comayagua and Santa Bárbara (both in the second region, called Yojoa Lake region). Five communities in the first region and four in the second region were studied. The PPB project was implemented with farmers who were members of local agricultural research committees (CIAL). Thus, in these communities, all PPB-participants were CIAL members. Within each community, 50-100% of PPB-participants (N=58) were randomly selected for interview and a similar number (N=57) of non-participants (non-CIAL) farmers were selected. Of the 120 farmers initially proposed for inclusion in the study, only 115 were interviewed and 108 valid surveys were obtained (half in each region). The data were collected in 2006.

To evaluate strengths, weaknesses and the economic impact of PPB, both descriptive and econometric approaches were used. The surveyed farmers were disaggregated by PPB-participation (i.e. participants and non-participants) and by region (i.e. Yoro and Yojoa Lake). A single-equation linear regression model was estimated to evaluate factors associated with differences in farmers' yields. In addition, net present value (NPV) analysis was done to determine whether investing in PPB has been profitable.

The socioeconomic differences between PPB-participants and non-participants were non-significant for most variables. However, on average, heads of participant households were more educated (3.7 yrs vs. 2.9 yrs of education; 10% SL) and had greater access to credit (85% vs. 51%; 1% SL). Access to credit was higher for PPB-participants because they had access to credit through their respective CIAL or ASOCIAL, one of the benefits from participating in these farmer groups.

In contrast, there were greater socioeconomic differences between regions. Households in the Yojoa Lake region were larger (5.5 vs. 4.7 members; 10% SL) and had almost one more adult with more than three years of education (1% SL). In addition, the share of adults with more than three years of education was higher (64% in Yojoa Lake vs. 41% in Yoro; 1% SL). However, farmers in the Yoro region had greater access to credit (76% vs. 61%; 10% SL)—possibly because communities in the Yoro region were closer to a small town, compared to communities in the Yojoa Lake region (9 km vs. 13 km, respectively).

Participant farmers, NGOs' staff, and scientists reported several strengths and weaknesses of the PPB project. The most important strengths were: (1) many varieties had been released and adopted through the communities, (2) farmers felt their expectations had been fulfilled, (3) capacity had been built, and (4) the PPB project reduced the time required for adoption of new varieties and increased the adoption rate of IVs (PPB varieties in this case).

The most important weaknesses were: (1) the project needed to increase direct contact with farmers, (2) the project was technologically and financially dependant on Zamorano and NGOs, (3) PPB needed to be scaled up, and (4) many non-participant farmers were not aware of the CIALs' PPB activities.

The PPB project benefitted farmers in many ways, including PPB knowledge acquisition, greater IV adoption, and higher yields. PPB-participants learned a great about the breeding process and this knowledge spread throughout the communities--many non-participant farmers learned about the breeding process from PPB participants.

As expected, traditional varieties were planted most widely, followed by PPB varieties and, far behind, by CPB varieties. *Macuzalito* was the most widely-planted PPB variety, while *Tío Canela 75* was the most widely-planted CPB variety. However, the number of hectares planted to *Tío Canela 75* was only equal to 11% of the area planted to *Macuzalito* in these regions. Low adoption of CPB varieties was expected, since the PPB projects were implemented in communities that had low adoption rates of CPB varieties. Furthermore, the PPB adoption curve showed that PPB varieties could reach their adoption ceiling in a short period of time (6 years after release).

Among the economic benefits, the main finding was that both PPB and CPB varieties yielded more than traditional varieties. Farmers who planted a PPB variety obtained an average yield that was 135 kg/ha greater than farmers planting a traditional variety. Additionally, CPB varieties yielded 358 kg/ha more than traditional varieties. Despite the extremely high difference in yields between CPB and traditional varieties, the economic impact of PPB varieties in these communities was 192% larger than that of CPB varieties, mainly due to the differences in area planted to these varieties. These results also suggest that CPB varieties may perform better than expected in these niche environments and that yield was not the only characteristic of importance to farmers because adoption of CPB varieties was very low, despite their high yield.

The NPV analysis showed that investments in the PPB project were profitable. However, the project bordered on becoming unprofitable (i.e. NPV<0) because the IRR was very close to the discount rate used for the NPV estimations. The sensitivity analysis showed that the project may become more profitable if additional investments are made to (a) increase the yield of future PPB varieties (assuming the process will continue) or (b) additional efforts are devoted to promoting the use of PPB varieties to increase adoption rates. To implemented PPB with other CIALs in other regions of Honduras, stakeholders should: *first* carefully consider how many CIALs are required to implement PPB; *second*, select CIALs with different environmental conditions than the CIALs that have already released PPB varieties; *third*, select farmers who have received previous training in research methodologies as PPB-participants*; fourth*, develop PPB varieties with higher yield advantage (compared to traditional varieties) than current ones; and *fifth*, increase efforts to promote the use of PPB varieties.

Finally, the PPB projects will continue to depend on Zamorano's breeding program to obtain segregating lines to start the breeding process and on Zamorano and NGOs for financial and technical support.

5.2 Implications for PPB stakeholders

Farmers have benefited from the PPB project in many ways. *First*, their expectations about what they were going to learn from the project were met. *Second*, farmers were satisfied with the roles played by the organizations in charge of implementing the project (although they would like more technical and financial assistance). *Third*, they learned how to select lines to develop bean varieties and about crop management techniques. *Fourth*, farmers who planted participatory bred varieties obtained higher yields than farmers who planted traditional varieties. *Fifth*, investments in the project were profitable, given the assumptions used in evaluating the NPV of the

PPB project. Using these results, the following policy recommendations are made to stakeholders.

CIAL members

To increase the economic impact of the bean varieties developed by CIAL members, more promotion should be done to increase the adoption rates. The data show that adoption (measured by the percent of the bean area planted to PPB varieties) was relatively low among non-participant farmers and among farmers in the Yojoa Lake region. Therefore, if CIAL members promote these varieties (e.g. through mouth-to-mouth communication, increased attendance to demonstrative fields, distributing informative pamphlets about the varieties), non-adopters may become adopters and the benefits would be larger.[105] Especially in the Yojoa Lake region, a greater effort should be made to promote PPB varieties, since adoption was lower than in the Yoro region. This will require CIALs to produce enough high-quality low-cost seed; otherwise, farmers will not be able to adopt PPB varieties.

Since almost one-third of non-participant farmers were not aware of the CIAL's activities (although some had heard about the bean PPB project, mainly from CIAL members),[106] the feedback stage should be strengthened. Strengthening the feedback stage will increase awareness of CIAL activities and increase adoption.

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[105] Promotion activities should be a coordinated effort between CIAL members and NGOs.

[106] Among non-participants, 45% had heard about the bean PPB project (less than one-third of them were former CIAL members). From these, 30% reported learning about the project from CIAL members, 25% from the CIAL extensionist, and 21% from NGO's staff.

The results also suggest that stakeholders need to develop PPB bean varieties that yield more than the current ones. Furthermore, farmers reported that current varieties were susceptible to diseases (e.g. angular leaf spot), especially the varieties developed in the Yojoa Lake region. Therefore, new PPB varieties should include genes that make them resistant to the main diseases present in their niche environments.

Two CIALs (one in each region) included only female members (one of these was excluded from this study, since it was just starting PPB). However, Yojoa Lake farmers reported that female participation in PPB was low. Addressing this weakness may be difficult since women usually take care of the household needs (e.g. cooking, cleaning, kids and elderly care). Therefore, their time may be limited.

Zamorano and Non-Governmental Organizations

The results suggest that both Zamorano and NGOs should: (1) Help farmers to develop varieties with higher yields and greater resistance to diseases, compared to current ones (medium to long term objective). A short-term alternative could be to increase farmers' access to inputs, especially fertilizer, which reduced yields by 334 kg/ha when not applied.[107] (2) Assist farmers to promote current PPB varieties to increase adoption in order to increase the economic impact in the two regions, especially in the Yojoa Lake region. The sensitivity analysis showed that if yields or adoption rates were increased, the NPV of the project would greatly increase. This will require CIALs to produce high-quality low-cost seed and make it available to farmers. Otherwise,

[107] Farmers seldom apply the recommended levels of inputs because they have limited resources. Thus, most farmers would require access to credit to finance input purchases.

promoting these varieties will have no results since farmers will not be able to adopt them.

(3) These organizations should be careful to select a minimum number of high-quality CIALs with different environmental conditions to implement PPB.[108] (4) Zamorano and NGOs should provide additional technical assistance to the CIALs, especially in the Yoro region. This may be a challenge because it will require additional (monetary and human) resources. (5) Finally, one challenge for this study was to collect information related to the cost of the project. Given that records were not available, estimations from Zamorano's and NGOs' staff were used. In the future, these organizations should keep better track of their PPB expenses, so it would be possible to more accurately estimate the cost of implementing PPB.

While developing (new) PPB varieties with higher yields will be a challenge, it should be given priority. Furthermore, given that *Macuzalito* was the most widely used PPB variety, it will be beneficial to test its adaptability to other niche environments. If trials in other locations show that *Macuzalito* performs well, it may be possible for the farmers to obtain permission from the government to sell it as certified seed. Furthermore, if this variety performs well, the economic impact of PPB would be greater since more farmers would adopt it.

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[108] Implementing PPB in communities in different environmental niches (perhaps located away from each other) may increase the cost of technical assistance. These (increased) cost should be considered, since increased cost could make the project become unprofitable.

Donors

The results suggest that, in addition to continue to support PPB, efforts should be directed at two main areas: (1) Generating PPB varieties with higher yields, compared to current ones, and (2) promoting the use of PPB varieties to increase adoption. To do this, additional staff, technical assistance, improved feedback to community members, and scaling up PPB to other regions may be necessary. Therefore, Zamorano and NGOs should seek additional funds from donors to strengthen the PPB project in order to augment the economic impact of PPB in the country. Consequently, donors are key to the continued success of the PPB project.

Government

Currently, there is no government involvement in the PPB project (except when a variety is released). This is understandable because the project targets niche environments, which may not be of primary interest to the government. However, stakeholders felt they would greatly benefit if the government provided technicians to assist in implementing the project, or if it facilitated the commercialization of (certified) seed of PPB varieties. Currently, PPB varieties can't be freely marketed (i.e. sold as certified seed) because they are developed for niche environments. If the government allows PPB varieties to be sold in labeled bags,[109] this would provide an incentive for CIAL members to increase seed production, which could benefit a greater number of farmers.

[109] Even if some restrictions are put in place (e.g. limitations to the area where the seed could be sold).

5.3 Limitations of the Study

One limitation of the study is that the results are only representative of the communities where PPB projects were being implemented at the time of the study. Thus, the control group of non-participants may not be a valid control group because they may have been exposed to spillovers from the CIAL work.

Another limitation is that the study didn't include an analysis of the determinants of CIAL participation (i.e. why some farmers choose to be members of the CIAL while others don't). Results of this type of analysis could be used to increase (or maintain) CIAL membership, hence increasing the success of the PPB initiatives. Humphries *et al*. (2005) reported that the major problem to maintain membership in the Yojoa Lake region was the proximity of this region to San Pedro Sula, the major commercial town in the country. Because farmers (including CIAL members) migrate to San Pedro Sula several times per year to work, the continuity of PPB is undermined as PPB participants leave the group. This may partially explain low adoption levels found in the Yojoa Lake region.

Furthermore, analysis is needed to learn why some CIALs are more successful than others in releasing PPB varieties. This information could be useful when choosing the CIALs to scale up PPB, since stakeholders could use this information to select CIALs with a high chance of success.

Finally, the study does not include an analysis of alternative ways to market PPB varieties in order to make them more widely available and increase adoption.

5.4 Future Research

Future research could focus in the following areas. As mentioned in the previous section, studying the determinants of CIAL participation would be helpful in better understanding why farmers participate in groups (i.e. CIAL). Similarly, research is needed to better understand the characteristics of the CIALs that have been successful in releasing PPB varieties, so CIALs with similar "successful" characteristics are selected when scaling up the project.

Research could also be conducted to identify alternative ways to commercialize/make available the seed of PPB varieties generated by CIAL farmers. To increase adoption and the impact of PPB, it is necessary to make high-quality low-cost seed available to farmers. Additionally, is important to investigate how the government could become involved in PPB projects.

Finally critics argue that PPB may become unprofitable, if the number of PPB projects that are needed is too high. Thus, research should be done to characterize bean-growing environments in Honduras in order to identify the locations with similar niche environments. This information could be used to estimate the equilibrium number of CIALs that should implement PPB and areas where varieties developed using PPB would likely perform well.

ANNEXES

Table A.1. Population information of communities evaluated in the departments of Yoro, Comayagua, and Santa Bárbara, Honduras, 2006.

Department	Municipality	Village	Community	Total # households	No. households in CIAL[1]	No. households in Non-CIAL	Sample[2] PPB	Sample[2] Non-PPB
Yoro	Yorito	Vallecillos	Mina Honda	37	11	26	6	6
Yoro	Yorito	Vallecillos	La Patastera	37	4	33	3	3
Yoro	Yorito	Pueblo Viejo	Santa Cruz	28	6	22	5	5
Yoro	Yorito	Pueblo Viejo	Pueblo Viejo	46	10	36	5	6
Yoro	Sulaco	La Albardilla	LR, LL, MG[3]	93	12	81	7	11
Comayagua	San José de Comayagua	Laguna Seca	Laguna Seca	73	16	57	12	5
Santa Bárbara	Concepción del Sur	Nueva Esperanza	Nueva Esperanza	125	6	119	6	8
Comayagua	Taulabé	El Palmichal	Palmichal	100	6	94	6	5
Comayagua	Siguatepeque	Buena Vista de Río Bonito	Buena Vista de Río Bonito	121	8	113	8	8
Yoro	Yorito	Yorito	--	460	n.a.	n.a.	n.a.	n.a.
Comayagua	Taulabé	Taulabé	--	1046	n.a.	n.a.	n.a.	n.a.

Source: INE (2001); Informal group discussions in 2006.

[1] CIAL = Local Agricultural Research Committee.

[2] For sample: PPB= participant farmers; Non-PPB= non-participant farmers.

[3] LR = Los Rincones; LL = Lomas Largas; MG = Monte Galán.

Table A.2. Average number of locations, lines and replications per line per nursery,[1] Zamorano, Honduras, 2000-2005.

	# locations/year							# lines/nursery							# replications/line						
Nursery	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Mean**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Mean**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Mean**
VIDAC	17	16	8	11	11	9	12	78	119	103	120	120	78	103	1	1	1	1	1	1	1
ECAR	13	10	6	7	7	6	8	16	16	16	16	16	16	16	3	3	3	3	3	3	3
COVA	n.p.	5	3	2	9	n.p.	5	n.p.	7	14	10	8	n.p.	10	n.p.	2	3	2	2	n.p.	2

Source: Programa de Investigaciones en Frijol (PIF) database, Zamorano, Honduras.
Notes: n.p. indicates the nursery was not planted that year.
[1] Includes all nurseries planted by collaborators throughout Central America.

Table A.3. Marginal costs of conventional (CPB) and participatory (PPB) plant breeding of beans per CIAL. Honduras, 2006.

		Average #		Plot size per bean line					Cost ($) per line per		Marginal cost per variety	
Year[1]	Stage	Loca-tions (A)	Lines[2] (B)	Rows/ line (C)	# Rep. (D)	Length (m) (E)	Width (m) (F)	Area (m^2) (G)	1,000 m^2 (H)	Loca-tion (I)	CPB ($) (J)	PPB ($)[7]
1	Crosses	1	50	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5	5	5
1	F1 generation	1	50	n.a.	n.a.	n.a.	n.a.	0.18	500	5	5	5
1	F2 generation	1	1,000	1	1	0.10	0.75	0.08	500	38	38	38
2	F3 generation	1	120	1	1	3	0.75	2.25	500	135	135	68
2	F4 generation	1	60	1	1	3	0.75	2.25	500	68	68	34
3	F5 generation	1	30	1	1	3	0.75	2.25	500	34	34	17
3	F6 generation	1	15	1	1	3	0.75	2.25	500	17	17	8
	Nurseries:[3]											
	LINAF/VIROS	4.5	5	1	2.5	3	0.60	4.50	500	11	51	n.a.
	VIDAC	12	4	1	1	3	0.60	1.80	1,618	12	140	n.a.
	ECAR	8	3	4	3	5	0.60	36	1,042	113	900	n.a.
4	COVA	5	2	10	2	10	0.60	120	417	100	500	200
4	Seed increase	1	1							1,000	1,000	250
	Farmer trials[4]	10	1					620		200	2,000	n.a.
	Releasing process:											
5	Demonstrative field	4	1							1,250	5,000	741
5	Field day	4	1							530	2,120	318
5	Seed for distribution[5]	1	1							3,000	3,000	750
5	Paperwork[6]	1	1							500	500	500
	Total marginal cost									**7,016**	**15,511**	**2,933**

Source: The author, based on information provided by Rosas (2006a); Escoto (2006); and Zamorano's bean program database.

Table A.3 (cont'd).

Notes: Rep. = repetitions per line; n.a. = not applicable; (G) = (C)x(D)x(E)x(F) for stages F2 thorugh COVA; (I) = [(B)x(G)x(H)]/1,000 for stages F1 through COVA; (J) = (A)x(I).

[1] Year is based on the PPB process, not the CPB process.

[2] The information in (B) is related to the 50 crosses required to release a variety. For example, the VIDAC usually includes more than 100 lines; however, only four will come from the 50 crosses.

[3] Assumes that, per location, each VIDAC and COVA cost $300, while each ECAR costs $600. The number of lines in (B) represents 3.9%, 18.7%, and 33.3% of the average number of lines in each VIDAC, ECAR, and COVA, respectively. Therefore, the costs in (I) reflect these percentages of the total cost per nursery.

[4] (G) was estimated assuming: 5 lb/trial, 22 g/100 seeds, 0.6 m between rows, and 0.1 m between seeds.

[5] (I) reflect the cost of producing 910 kg of 'basic' seed, which is distributed among participants during the field day.

[6] Includes: paperwork for registering the variety and printouts of varietal descriptors and crop management recommendations.

[7] Assumes that: 1) Stages F3-F6 will only require 50% of CPB cost because farmers test half the number of lines than under CPB; 2) Only two COVAs will be necessary; 3) Seed increase and seed for distribution will only require 25% of per location CPB cost because less seed is needed.

Table A.4. Cronbach's alpha test results for PPB knowledge scale. Honduras, 2006.

Test scale = mean (unstandardized items)

Item*	Obs	Sign	item-test correlation	item-rest correlation	average inter-item covariance	alpha
Question 1	108	+	0.7077	0.5967	0.1293	0.7629
Question 2	108	+	0.7087	0.6053	0.1310	0.7632
Question 3	108	+	0.7628	0.613	0.1108	0.7567
Question 4	108	+	0.5968	0.4364	0.1371	0.7888
Question 5	108	+	0.6813	0.5291	0.1257	0.7726
Question 6	108	+	0.5905	0.4145	0.1365	0.7942
Question 7	108	+	0.6948	0.5648	0.1272	0.7662
Test scale					0.1282	0.7984

Estimated correlation between scale and factor measured: $\boxed{0.8935}$

Interitem covariances (observations = 108 in all pairs)

Questions*	1	2	3	4	5	6	7
1	0.2617						
2	0.1215	0.2336					
3	0.1838	0.1760	0.5368				
4	0.0623	0.0639	0.1873	0.3395			
5	0.1620	0.1745	0.1816	0.0559	0.3984		
6	0.0997	0.0685	0.1357	0.1461	0.0897	0.3911	
7	0.1246	0.1231	0.1668	0.1205	0.1445	0.1052	0.3229

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

* See Table 4.4 for details about each question.

Table A.5. Reasons why farmers prefer different types of bean varieties, Yoro and Yojoa Lake regions, Honduras, 2006.

	Variety type[1]		
Detail	**TRA**	**PPB**	**CPB**
Variety preferred most[2]	Vaina Blanca	Macuzalito	Tio Canela 75
Farmers who preferred this variety (%)	25.0	55.7	50.6
Preferred variety because (% YES):			
High yields	54.7	54.4	73.0
Good market value	57.9	53.2	38.2
Good cooking quality	44.2	39.2	24.7
Good plant architecture	6.3	30.4	20.2
Disease and pest tolerant	11.6	10.1	16.9
Good adaptability	10.5	5.1	9.0
Earliness	10.5	6.3	3.4
Number of sample observations	96	79	89

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] TRA = Traditional variety; PPB = Participatory bred variety; CPB = Conventionally bred variety.

[2] Among all varieties planted within five years prior to this study.

Table A.6. Average area (ha) planted to each bean variety type in the *Primera* 2005 season, by PPB[1] participation and region. Honduras.

Variety type planted	PPB participant? No	PPB participant? Yes	P-value[2]	Region[3] Yoro	Region[3] Yojoa Lake	P-value[2]	Total
	(average # ha)						
Traditional	0.49	0.48	0.9794	0.64	0.34	*0.0651	0.48
Participatory bred (PPB)	0.09	0.21	**0.0323	0.28	0.04	***0.0000	0.15
Conventionally bred (CPB)	0.03	0.02	0.6036	0.02	0.04	0.2826	0.03
Number of sample observations	48	46	--	44	50	--	94

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] PPB = Participatory Plant Breeding.

[2] P-value is for a mean-difference t-test between PPB participants vs. non-participants and Yoro farmers vs. Yojoa Lake farmers, assuming equal variances. ***=significant at a 1% level; **=significant at a 5% level; *=significant at a 10% level.

[3] Includes both PPB and non-PPB farmers.

Table A.7. Average area (ha) planted to each bean variety type in the *Postrera* 2005 season, by PPB[1] participation and region. Honduras.

Variety type planted	PPB participant? No	PPB participant? Yes	P-value[2]	Region[3] Yoro	Region[3] Yojoa Lake	P-value[2]	Total
	(average # ha)						
Traditional	0.38	0.29	0.5090	0.39	0.12	*0.0799	0.33
Participatory bred (PPB)	0.24	0.38	0.2321	0.38	0.06	**0.0254	0.31
Conventionally bred (CPB)	0.01	0.03	0.3676	0.02	0.03	0.6060	0.02
Number of sample observations	25	29	--	43	11	--	54

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] PPB = Participatory Plant Breeding.

[2] P-value is for a mean-difference t-test between PPB participants vs. non-participants and Yoro farmers vs. Yojoa Lake farmers, assuming equal variances. ***=significant at a 1% level; **=significant at a 5% level; *=significant at a 10% level.

[3] Includes both PPB and non-PPB farmers.

Table A.8. Average number of hectares (ha) planted to different PPB[1] varieties in the 2005 agricultural year,[2] by PPB participation and region. Honduras.

	PPB participant?			Region[4]			
Variety Name	**No**	**Yes**	**P-value[3]**	**Yoro**	**Yojoa Lake**	**P-value[3]**	**Total**
				(average # ha)			
Macuzalito	0.31	0.32	0.8681	0.37	0.00	***0.0017	0.31
Marcelino	0.04	0.06	0.7412	0.06	0.00	0.2605	0.05
Nueva Esperanza 01	0.03	0.02	0.5946	0.00	0.16	***0.0000	0.02
Cedrón	0.00	0.04	0.1408	0.03	0.00	0.4249	0.02
Palmichal 1	0.01	0.02	0.3198	0.00	0.10	***0.0000	0.02
Cayetana 85	0.00	0.02	0.1962	0.02	0.00	0.4832	0.02
Number of sample observations	27	43	--	59	11		70

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

[1] PPB = Participatory Plant Breeding.

[2] Includes both the *Primera* and *Postrera* seasons.

[3] P-value is for a mean-difference t-test between PPB participants vs. non-participants and Yoro farmers vs. Yojoa Lake farmers, assuming equal variances. ***=significant at a 1% level; **=significant at a 5% level; *=significant at a 10% level.

[4] Includes both PPB and non-PPB farmers.

Table A.9. Adoption estimation for CPB and PPB varieties,[1] Yoro and Yojoa Lake regions, Honduras, 2006.

Year[2]	Adoption (% of area)[3]			
	t	**CPB**	**t**	**PPB**
1996	1	0.010		
1997	2	0.013		
1998	3	0.016		
1999	4	0.019		
2000	5	0.023		
2001	6	0.027		
2002	7	0.031		
2003	8	0.034	1	0.010
2004	9	0.037	2	0.077
2005	10	**0.040**	3	**0.316**
2006	11	0.042	4	0.485
2007	12	0.044	5	0.516
2008	13	0.045	6	0.520
2009	14	0.047	7	0.520
2010	15	0.047	8	0.520
2011	16	0.048	9	0.520
2012	17	0.049	10	0.520
2013	18	0.049	11	0.520
2014	19	0.049	12	0.520
2015	20	0.049	13	0.520
2016	21	0.050	14	0.520
2017	22	0.050	15	0.520
2018	23	0.050	16	0.520

Variety type[1]	t	At (A)	Amx[4] (B)	Amx-At (C)	At/(Amx-At) (D)	ln (D) (E)	$(E)_{current}$ - $(E)_{t=1}$	β	α
CPB	1	0.01	0.05	0.04	0.25000	-1.3863	2.7726	0.3081	-1.6944
CPB	10	0.04	0.05	0.01	4.00000	1.3863			
PPB	1	0.01	0.52	0.51	0.01961	-3.9318	4.3694	2.1847	-6.1165
PPB	3	0.316	0.52	0.20	1.54902	0.4376			

Logistic Adoption formula:

At = [Amx] / [1 + e^(-(α + β t))]

Therefore,

β = [$(E)_t$ - α] / t for *t* = {*1*, *current*} and for each variety type

For example, for CPB varieties:

β = [$(E)_{current}$ - $(E)_{t=1}$] / 9 = 2.7726 / 9 = 0.3081

And

α = $(E)_t$ - β t = (-1.3863) - 0.3081 = -1.6944

Source: B/C CRSP Survey of PPB project in Honduras, 2006.

Table A.9 (cont'd).

NOTES: At = adoption at time *t*; Amx = adoption ceiling.

[1] CPB=Conventionally bred; PPB= Participatory bred.

[2] *Tio Canela 75*, the CPB variety planted the most, was released in 1996. The first PPB variety was released in 2003. These years are used as t=1, respectively.

[3] Data in bold are from the survey; data for t=1 are assumed; all other data were estimated using the logistic adoption formula.

[4] The ceiling adoption rates are 5% for CPB varieties and 52% for PPB varieties.

Table A.10. Participatory Plant Breeding Project Budget (Base Scenario), Yoro and Yojoa Lake regions, Honduras, 2006.

Item[1]	w/o project	with project year 1	2	3	4	5	6	7	8	9	10	11	12 to 20
INFLOWS													
(A) Average Yield increase (kg/ha)[2]	0	0	0	0	0	135	135	135	135	135	135	135	135
(B) Price ($/kg)	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
(C) Value of production ($/ha)	0	0	0	0	0	89	89	89	89	89	89	89	89
(D) PPB planted area (ha/yr)[3]	0	0	0	0	0	1.0	7.6	31.1	47.7	50.8	51.1	51.2	51.2
(E) Total value ($/yr)	0	0	0	0	0	89	677	2,771	4,250	4,526	4,553	4,562	4,562
OUTFLOWS													
Investments													
(F) Breeding materials ($/yr)[4]		47	101	25	450	1,809							
(G) Adjusted (F) ($/yr)[5]		282	608	152	2,701	9,045							
(H) Avg. No. farmers (per CIAL/yr)		9	9	9	9	9							
(I) No. days worked per year[6]		9.3	12.3	14.3	14.3	14.3							
(J) Opportunity cost of labor ($/day)		2.32	2.32	2.32	2.32	2.32							
(K) Total labor per CIAL ($/yr)		194	257	299	299	299							
(L) No. of CIALs		9	9	9	9	9							
(M) Total labor investment ($/yr)		1,748	2,311	2,687	2,687	2,687							
(N) Total Investments in PPB ($/yr)	0	2,030	2,919	2,839	5,388	11,732							
Average Operational Costs													
(O) Production cost increase ($/ha)[7]	0	0	0	0	0	0	0	0	0	0	0	0	0
(P) Total AOC ($/yr)	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.10 (cont'd).

Item[1]	w/o project	with project year 1	2	3	4	5	6	7	8	9	10	11	12 to 20
(Q) Total outflows ($/yr)	0	2,030	2,919	2,839	5,388	11,732	0	0	0	0	0	0	0
Net Benefit													
(R) Total	0	-2,030	-2,919	-2,839	-5,388	-11,643	677	2,771	4,250	4,526	4,553	4,562	4,562
Incremental		-2,030	-2,919	-2,839	-5,388	-11,643	677	2,771	4,250	4,526	4,553	4,562	4,562
NPV[8] =	**969**		**IRR =**	**10.73**									

Source: Estimations made by the Author.

[1] (C) = (A)*(B); (E) = (C)*(D); (G) = (F)*6 for years 1-4; (G) = (F)*5 for year five; (K) = (H)*(I)*(J); (M) = (K)*(L); (N) = (G)+(M); (P) = (D)*(O); (Q) = (N)+(P); (R) = (E)-(Q).

[2] Assumes that PPB varieties yield, on average, 135 kg/ha more than traditional varieties.

[3] Planted area estimated from multiplying the share of bean area planted to PPB varieties (from Table A.9) times the total bean area in the sample (i.e. 98.4 ha).

[4] See Table A.3. for details. It excludes paperwork costs (in year 5) since these don't add any quantifiable benefits to PPB varieties.

[5] Adjusted by the number of varieties released. For years 1-4, six sets of breeding materials were used; however, in year five, only 5 varieties were released.

[6] Sum of days spent on meetings per year and days spent on fieldwork per year (see Table 4.13 for details).

[7] It is assumed that production costs will remain the same.

[8] A 10% discount rate was assumed.

Table A.11. Participatory Plant Breeding Project Budget (Scenario B), Yoro and Yojoa Lake regions, Honduras, 2006.

Item[1]	w/o project	with project year 1	2	3	4	5	6	7	8	9	10	11	12 to 20
INFLOWS													
(A) Average Yield increase (kg/ha)[2]	0	0	0	0	0	203	203	203	203	203	203	203	203
(B) Price ($/kg)	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
(C) Value of production ($/ha)	0	0	0	0	0	134	134	134	134	134	134	134	134
(D) PPB planted area (ha/yr)[3]	0	0	0	0	0	1.0	7.6	31.1	47.7	50.8	51.1	51.2	51.2
(E) Total value ($/yr)	0	0	0	0	0	134	1,018	4,167	6,391	6,806	6,846	6,860	6,860
OUTFLOWS													
Investments													
(F) Breeding materials ($/yr)[4]		47	101	25	450	1,809							
(G) Adjusted (F) ($/yr)[5]		282	608	152	2,701	9,045							
(H) Avg. No. farmers (per CIAL/yr)		9	9	9	9	9							
(I) No. days worked per year[6]		9.3	12.3	14.3	14.3	14.3							
(J) Opportunity cost of labor ($/day)		2.32	2.32	2.32	2.32	2.32							
(K) Total labor per CIAL ($/yr)		194	257	299	299	299							
(L) No. of CIALs		9	9	9	9	9							
(M) Total labor investment ($/yr)		1,748	2,311	2,687	2,687	2,687							
(N) Total Investments in PPB ($/yr)	0	2,030	2,919	2,839	5,388	11,732							
Average Operational Costs													
(O) Production cost increase ($/ha)[7]	0	0	0	0	0	35	35	35	35	35	35	35	35
(P) Total AOC ($/yr)	0	0	0	0	0	35	266	1,089	1,670	1,778	1,789	1,792	1,792

Table A.11 (cont'd).

Item[1]	w/o project	with project year 1	2	3	4	5	6	7	8	9	10	11	12 to 20
(Q) Total outflows ($/yr)	0	2,030	2,919	2,839	5,388	11,767	266	1,089	1,670	1,778	1,789	1,792	1,792
Net Benefit													
(R) Total	0	-2,030	-2,919	-2,839	-5,388	-11,633	752	3,078	4,721	5,028	5,058	5,068	5,068
Incremental		-2,030	-2,919	-2,839	-5,388	-11,633	752	3,078	4,721	5,028	5,058	5,068	5,068
NPV[8] =	**3,001**		**IRR =**	**12.14**									

Source: Estimations made by the Author.

[1] (C) = (A)*(B); (E) = (C)*(D); (G) = (F)*6 for years 1-4; (G) = (F)*5 for year five; (K) = (H)*(I)*(J); (M) = (K)*(L); (N) = (G)+(M); (P) = (D)*(O); (Q) = (N)+(P); (R) = (E)-(Q).

[2] Assumes that PPB varieties yield, on average, 203 kg/ha more than traditional varieties.

[3] Planted area estimated from multiplying the share of bean area planted to PPB varieties (from Table A.9) times the total bean area in the sample (i.e. 98.4 ha).

[4] See Table A.3. for details. It excludes paperwork costs (in year 5) since these don't add any quantifiable benefits to PPB varieties.

[5] Adjusted by the number of varieties released. For years 1-4, six sets of breeding materials were used; however, in year five, only 5 varieties were released.

[6] Sum of days spent on meetings per year and days spent on fieldwork per year (see Table 4.13 for details).

[7] Production costs increase by $35/ha. Calculated using data from Tshering (2002).

[8] A 10% discount rate was assumed.

Table A.12. Participatory Plant Breeding Project Budget (Scenario C), Yoro and Yojoa Lake regions, Honduras, 2006.

Item[1]	w/o project	with project year											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12 to 20**
INFLOWS													
(A) Average Yield increase (kg/ha)[2]	0	0	0	0	0	135	135	135	135	135	135	135	135
(B) Price ($/kg)	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
(C) Value of production ($/ha)	0	0	0	0	0	89	89	89	89	89	89	89	89
(D) PPB planted area (ha/yr)[3]	0	0	0	0	0	1.0	7.2	31.1	52.5	57.3	58.0	58.1	58.1
(E) Total value ($/yr)	0	0	0	0	0	89	640	2,771	4,673	5,103	5,164	5,173	5,173
OUTFLOWS													
Investments													
(F) Breeding materials ($/yr)[4]		47	101	25	450	1,809							
(G) Adjusted (F) ($/yr)[5]		282	608	152	2,701	9,045							
(H) Avg. No. farmers (per CIAL/yr)		9	9	9	9	9							
(I) No. days worked per year[6]		9.3	12.3	14.3	14.3	14.3							
(J) Opportunity cost of labor ($/day)		2.32	2.32	2.32	2.32	2.32							
(K) Total labor per CIAL ($/yr)		194	257	299	299	299							
(L) No. of CIALs		9	9	9	9	9							
(M) Total labor investment ($/yr)		1,748	2,311	2,687	2,687	2,687							
(N) Total Investments in PPB ($/yr)	0	2,030	2,919	2,839	5,388	11,732							
Average Operational Costs													
(O) Production cost increase ($/ha)[7]	0	0	0	0	0	0	0	0	0	0	0	0	0
(P) Total AOC ($/yr)	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.12 (cont'd).

Item[1]	w/o project	with project year 1	2	3	4	5	6	7	8	9	10	11	12 to 20
(Q) Total outflows ($/yr)	0	2,030	2,919	2,839	5,388	11,732	0	0	0	0	0	0	0
Net Benefit													
(R) Total	0	-2,030	-2,919	-2,839	-5,388	-11,643	640	2,771	4,673	5,103	5,164	5,173	5,173
Incremental		-2,030	-2,919	-2,839	-5,388	-11,643	640	2,771	4,673	5,103	5,164	5,173	5,173
NPV[8] =	**3,073**		**IRR =**	**12.17**									

Source: Estimations made by the Author.

[1] (C) = (A)*(B); (E) = (C)*(D); (G) = (F)*6 for years 1-4; (G) = (F)*5 for year five; (K) = (H)*(I)*(J); (M) = (K)*(L); (N) = (G)+(M); (P) = (D)*(O); (Q) = (N)+(P); (R) = (E)-(Q).

[2] Assumes that PPB varieties yield, on average, 135 kg/ha more than traditional varieties.

[3] Planted area estimated from multiplying the share of bean area planted to PPB varieties (adoption ceiling of 59%) times the total bean area in the sample (i.e. 98.4 ha).

[4] See Table A.3. for details. It excludes paperwork costs (in year 5) since these don't add any quantifiable benefits to PPB varieties.

[5] Adjusted by the number of varieties released. For years 1-4, six sets of breeding materials were used; however, in year five, only 5 varieties were released.

[6] Sum of days spent on meetings per year and days spent on fieldwork per year (see Table 4.13 for details).

[7] It is assumed that production costs will remain the same.

[8] A 10% discount rate was assumed.

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