WH I TE 19ker

IMPROVED BEAN VARIETIES AND CULTIVATION PRACTICES IN EASTERN-CENTRAL AFRICA

ECONOMIC AND SOCIAL BENEFITS

Robert Kalyebara, Dymphina Andima, Roger Kirkby and Robin Buruchara

Pan-Africa Bean Research Alliance
PABRA

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

December 2008

AUTHOR AFFILIATIONS

Robert Kalyebara, Agricultural Economist, Pan Africa Bean Research Alliance, CIAT Africa Region Office, Kawanda Agricultural Research Institute, P.O. Box 6247, Kampala, Uganda. rkalyebara@hotmail.com

Dymphina Andima, Sociologist, Kenya Agricultural Research Institute, Regional Research Centre, Kisii, Box 523, Kisii, Kenya. dymphinaandima@yahoo.com

Roger Kirby, CIAT People and Agro-ecosystems Program Coordinator, c/o Kawanda Agricultural Research Institute, P.O. Box 6247, Kampala, Uganda. r.kirkby@cgiar.org

Robin Buruchara. CIAT Africa Region Coordinator, c/o Kawanda Agricultural Research Institute, P.O. Box 6247, Kampala, Uganda. r.buruchara@cgiar.org

CITATION

Kalyebara M. R., Andima Dymphina, Roger Kirkby and Robin Buruchara. 2008. Improved Bean Varieties and Cultivation Practices in Eastern-Central Africa: Economic and Social Benefits. Centro Internacional de Agricultura Tropical - CIAT. Cali, Colombia.

ACKNOWLEDGEMENTS

Financial support from PABRA, CIDA, SDC, DfID and USAID is highly appreciated. We thank all CIAT and PABRA network staff for their assistance in conducting and implementing the various studies. We are highly indebted to the farmers for their patience and cooperation during the surveys and also thank internal and external reviewers, scientists and country partners for their collaboration and insights.

LIST OF ABBREVIATIONS

CBO	Community Based Organization
CIAT	Centro International de Agricultura Tropical
CIDA	Canadian International Development Agency
DfID	Department for International Development (Britain)
DRC, DR Congo	Democratic Republic of Congo
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistics Division
GDP	Gross Domestic Product
GRB	Gross Research Benefits
HA	Hectare
IBMT	Improved Bean Management Technology
INERA	Institut National pour l'Etude et la Recherche Agronomiques
IRR	Internal Rate of Return
m.a.s.l	Meters above sea level
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
NPV	Net Present Value
NRB	Net Research Benefits
PABRA	Pan African Bean Research Alliance
R&D	Research and Development
ROR	Rate Of Return
SARI	Selian Agricultural Research Institute
SDC	Swiss Development Corporation
SSA, SS Africa	Sub-Saharan Africa
USAID	United States Agency for International Development.
US$	U.S. Dollars

CONTENTS

LIST OF FIGURES

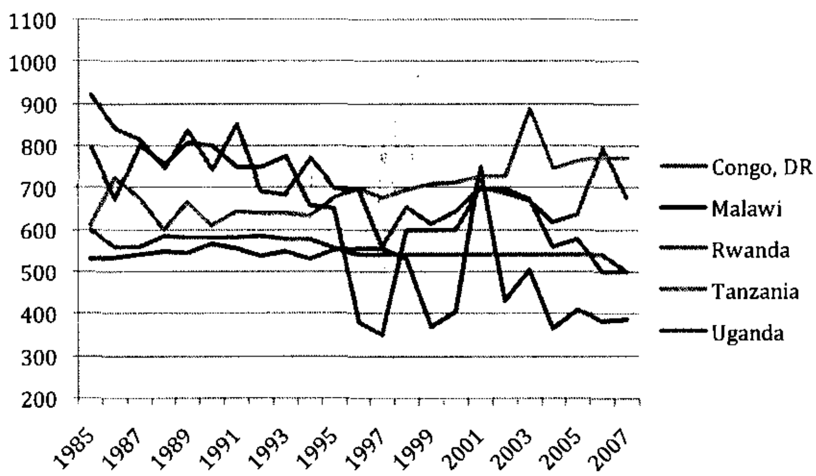
LIST OF TABLES

1. Introduction

The common bean, *Phaseolus vulgaris,* is a staple crop and food in many developing countries. In Sub-Saharan Africa (SSA) where the number of poor remains over 50% of the population (Chen and Ravallion, 2008), beans are an important and cost-effective protein source. Beans play a dual role of providing food security and generating income. Harvests are both consumed at home and sold for cash to make essential household purchases (De Steenhuijsen Piters, 1995). Beans are especially important to women. In much of SSA, women cultivate, cook and sell beans. Furthermore, the capacity of beans to fix nitrogen in soil can help improve the productivity and resilience of many different agricultural systems in Africa (Mugabe, 1994).

Inconsistent harvests threaten rural livelihoods in much of SSA (World Bank, 2007). Pests and diseases, drought and heat can reduce productivity and even cause crop failure. National-level statistics of inconsistent and worsening bean yields reflect persistent productivity challenges in many SSA countries (Figure 1).

Figure 1. Average bean yields of study countries (kg/ha), 1985 - 2007



To address these challenges, a partnership (PABRA) between the Centro Internacional de Agricultura Tropical (CIAT), National Agricultural Research Systems (NARs), and other research and development partners collaboratively developed and disseminated improved bean varieties and cultivation practices (i.e. bean technologies). By 2005, 184 improved bean varieties were disseminated in over 17 countries (5–20 per country). Some varieties have been adopted in multiple countries due to their wide agro-ecological and market suitability (Kimani, et al., 2008).

The objective of this paper is to estimate the economic, social and environmental benefits generated from bean investments in D.R. Congo, Malawi, Rwanda, Tanzania and Uganda. These countries contain substantial bean cultivation areas (Wortmann, et al. 1998). Between 1980 and 2004, over US$16 million has invested on bean research for Sub-Saharan Africa. This paper presents: (1) analysis of household-level impacts of new bean technologies, (2) extrapolation results that provide aggregate measures of impact, and (3) estimates of the rate of return to investments in bean R&D.

From 1986-2015, the net benefit from the US$16 million investment in eastern and central Africa beans is approximately US$199 million. The average return to the total investment is 41% with substantial variation across countries (DRC-Kivu 40%, Malawi 37%, Rwanda 34%, Tanzania 25%, and Uganda 71%). The highest R&D benefits were realized in countries with high annual bean output, acreage adoption, and yield gains.

2. BEAN MARKETS IN AFRICA

In Africa, beans have local, national and international marketability. Many farmers directly sell their harvest in local markets. At national levels, beans are used in the food industry for canning and as a major ingredient in weaning foods. Cross-border trade is growing from seasonal supply variations and demand in specialty high value markets of elite consumers major cities such as Nairobi, Kampala, Dar-es salaam, and Mombasa (ECABREN, 2005; Tchale, 2001). The growing awareness about the health benefits of beans in reducing cholesterol, and a source of soluble dietary fiber, has led to growing demand in export markets in Europe, America, and Asia.

The estimated total value of Africa's bean output at farm gate prices is over US$800 million per annum, out of which 95% is produced in Sub-Saharan Africa (

Table 1). Compared to a purely traded cash crop, Africa's coffee earnings are US$1 billion per annum. Nevertheless, Africa has a bean trade deficit of US$95 million, which implies additional production and market opportunities exist.

Table 1. Bean exports, imports, trade balance and value, (average 2002-4, x US$ 1000)

	Exports	Imports	Trade Balance	Output Value at Farm Gate
SS Africa	*26,901*	*67,391*	*-40,490*	*795,288*
DR Congo	-	3,867	-3,867	32,517
Malawi	336	657	-321	28,329
Rwanda	2	2,521	-2,519	68,452
Tanzania	5,363	2,495	2,868	83,000
Uganda	2,552	2,346	206	156,100

Source: FAO, 2005.

3. The Pan-Africa Bean Research Alliance

In 1996, African bean research and development organizations formalized their collaborative arrangement with the founding of the Pan-Africa Bean Research Alliance (PABRA).[1] Members include 24 National Agricultural Research Systems (NARS) of SSA, an international research organization (CIAT) and donor organizations. Since inception, CIDA, SDC and USAID have contributed to the alliance. The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), DFID of the UK and the Rockefeller Foundation also have supported components of the PABRA agenda. In addition, many additional partners contribute to and participate in PABRA's research and development (R&D) program: non-governmental organizations (NGOs), community-based organizations (CBOs), selected rural communities, farmers (seed producers and on-farm researchers), traders and the commercial private sector.

PABRA functions as a forum to build and maintain R&D linkages where partners share research experiences and results. The alliance structure and process fosters critical review and innovation. In 2002, PABRA partners designed a pan-Africa research and development (R&D) framework based on a common vision and objectives. PABRA initiated this analysis of R&D impacts to inform their decisions.

[1] The alliance is a consortium of two regional bean networks: the Eastern and Central Africa Bean Research Network (ECABREN) and the Southern Africa Bean Research Network (SABRN).

Numerous field studies revealed that a core set of widely-disseminated bean varieties generated significant beneficial impacts to both small-scale farmers and low-income consumers. Research indicated high adoption rates, with 60% to 100% of farmers adopting new bean varieties at numerous pilot sites (Mafuru, et al., 1995; Ndakidemi, et al., 1995; David, 1997; Kweka, et al., 1998; David, et al., 1998; David, et al., 2000; Phiri, et al., 2000; Odendo, et al., 2002). Evidence also showed significant increases in household bean output and consumption (Odendo, et al., 2002; Phiri, et al., 2000; David, et al., 2000; David & Sperling, 1999; Nkonya, et al., 1998; Sperling, et al., 1994; Mushi and Edje, 1989). These studies, however, also documented that degree of success was location-specific. Intensity of seed dissemination effort greatly affected adoption rates (Odendo, et al., 2002; David, et al., 2002; David and Sperling, 1999).

Based on these results, PABRA adjusted its R&D framework to emphasize scaling up and dissemination of improved bean cultivars and cultivation practices. Specifically, PABRA and member countries increased efforts to disseminate improved seed and strengthen seed systems. In 2003, PABRA initiated a 5-year R&D program, the *wider impact strategy*, with the aim of stimulating more utilization of bean technologies by ensuring that by 2008 10 million people in 17 countries were reached and would be using improved bean varieties.

4. DATA

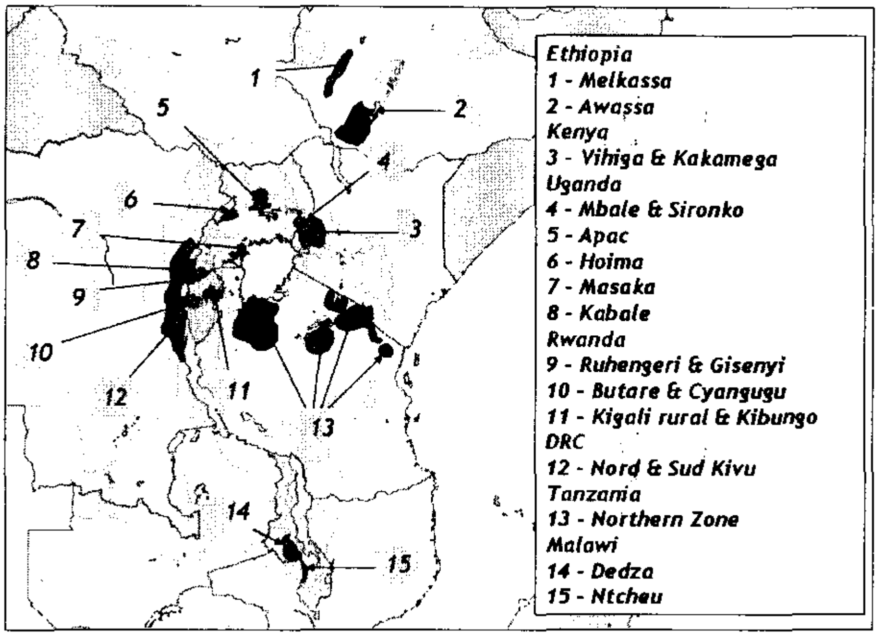
From 2004 to 2006, PABRA scientists coordinated a set of field research activities in seven countries in the eastern - central region of Africa (Figure 2). This paper presents results from five countries: DR Congo, Malawi, Rwanda, Tanzania and Uganda.[2] Data for the country studies were obtained through informal interviews and formal surveys of 1,983 farm households (

Survey questions included farmer estimates of household bean production, yields, consumption and sales for one year; gender relations and child nutrition resulting from bean consumption. Additional bean information came from research reports and publications from NARS and CIAT, national Ministries of Agriculture, and the FAOSTAT database.

[2] These five national-level studies are listed in the appendix, along with studies not included in this paper (Ethiopia and Kenya).

Table 2). In each country, a multistage sampling procedure was used to select a sample of bean farmers. Selection criteria included three factors: nationally-defined agro-ecological zone, bean farming system, and administrative district.

Figure 2. Map of study sites



Survey questions included farmer estimates of household bean production, yields, consumption and sales for one year; gender relations and child nutrition resulting from bean consumption. Additional bean information came from research reports and publications from NARS and CIAT, national Ministries of Agriculture, and the FAOSTAT database.

Table 2. Country survey sample size

Country	Households Surveyed
DR Congo	240
Malawi	525
Tanzania	306
Rwanda	383
Uganda	529

5. Methods

Data analysis emphasized the estimation of economic and social impacts. Economic and social impacts addressed changes in household food consumption, food security, and income generation by gender and wealth group. Although the adoption of faster-cooking varieties reduced fuelwood consumption, the value of this beneficial environmental impact was not estimated.[3]

Bean investments, adoption and impacts are estimated over a period of 30 years (1986-2015). Economic and social impacts at household level were analyzed by comparing descriptive statistics and Analysis of Variance (ANOVA). Estimates of output, consumption, income and food security parameters were disaggregated by gender, wealth category, and adoption levels. Household food security was assessed using three variables. If during the year the household realized an improvement in the: (a) amount of beans available for home consumption, (b) frequency of eating beans, (c) number of days the household had sufficient beans to eat.

Estimating adoption

During the period 1986-2005, 184 improved bean varieties were released along with region-specific recommendations on improved bean management practices. Any varieties or crop management practices adopted prior to 1986 are considered "old" technology. Acreage cultivated in new improved varieties is used to estimate adoption levels. Nevertheless, the estimated yield gains are attributed to the adoption of both improved bean varieties and management practices. Farmers who adopted only agronomic practices are not considered adopters. Due to interactions between variety and management practices and the difficulty of obtaining the required farm-level data, the impact of new varieties from improved cultivation practices was not disaggregated. A household is

[3] Nkonya *et al* (1998) estimated the fuelwood saved by switching from Canadian wonder (variety with a long cooking time) to Lyamungu 85 (improved variety with a shorter cooking time). The authors estimated the fuelwood required for cooking Lyamungu 85 at 188 Kg/household/year and that of Canadian wonder at 364 kg/household/year. Switching from Canadian wander to Lyamungu 85 saves 176 kg/household/year of fuelwood.

considered an adopter if it had grown at least one new variety for two or more seasons and was continuing to use the variety. Due to intercropping of beans, standard acreage-based estimates of adoption could not be obtained accurately. Therefore, adoption rate was estimated as the quantity of new variety seed planted in a year as a proportion of the total weight of bean seed planted.

A trapezoidal adoption trend estimates the use of new varieties over time. The adoption rate is estimated for a 30 year period (1986 to 2015). For each country, the year of initial variety release was obtained from CIAT. Household survey and historical data on seed dissemination were used to estimate annual adoption and the expected adoption ceiling (Table 3).

Table 3. Estimated adoption rates for new bean varieties

Location	Year when first new varieties were released	Bean area planted with new varieties (% in 2005)	Adoption ceiling (% bean acreage in new varieties)	Expected year when adoption ceiling reached
DRC-Kivu	1989	70	80	2007
Malawi	1993	70	80	2007
Rwanda	1985	40	60	2008
Tanzania	1985	60	80	2008
Uganda	1994	45	60	2008

ESTIMATING AGGREGATE BENEFITS OF BEAN R&D

Total benefits to society are estimated using an economic surplus model (Alston, et al. 1998). Aggregate net research benefits (NRB) are calculated as the aggregate gross research benefits (GRB) to bean producers and consumers less research and development costs (RDC), and less any change in costs of production (C) incurred by farmers.

Gross research benefits are the sum of net profits accruing to bean producers (producer surplus) who adopt the new bean technologies; and the benefits to consumers (consumer surplus) usually in form of lower-price beans. Gross producer benefits are calculated by multiplying the area planted to an improved variety by the yield gain, the market price, and the adoption rate. The yield gain is calculated as the difference in yield between the local and improved variety under similar farm conditions. The market price is the farm gate price received by farmers in each year. The calculation of the number of beneficiaries was determined by similarity of the areas sampled to wider areas of the country. Therefore, extrapolation domain was all of Malawi and Rwanda, northern Tanzania, multiple zones in Uganda and the Kivu Province in the DRC (Figure 2).

The economic surplus model is estimated on the assumption that beans are largely a non-traded commodity. Most local output consumed at home or traded in the domestic market. Although some countries export or import beans, the quantity is assumed insufficient to influence regional bean prices. While anecdotal evidence exists of spill-over effects arising from international trade in beans and germplasm exchange with countries not included in this analysis, these spillovers are not included due to the limited scope of the study.

Numerous African studies have employed economic surplus estimation techniques to calculate benefits and rates of return to R&D investments (Sanders, 1994; Thirtle & Van Zyl, 1994; Ahmed et al., 1995; Isinika, 1995; Khatri et al., 1996; Mills and Karanja, 1997; and Kaliba et al., 1999, Kalyebara, 2001). A few of these studies examined bean impact. Evidence on other similar commodities is used for comparison. For example, in Uganda, Laker-Ojok (1994) estimated rates of return (ROR) to research of maize and oilseeds. Wessler, et al. (1999) estimated internal rates of return to research and extension.

ESTIMATING COSTS

Adoption costs per hectare were estimated from cost of production estimates 'with' and 'without' new technologies. Data on cost of production of beans was obtained from the survey as well as bean network research reports. The change in marginal cost per ton (k) as a result of the new technology is calculated by dividing the proportionate yield gain (dY) by the supply elasticity, net of the adoption cost per ton (c).

k = {(proportional increase in production (dY/Y)/supply elasticity (E_s)} - adoption cost per ton (c)

Research and development costs include administration and overhead expenditures, staff salaries and benefits, the cost of development and testing of varieties and cultivation practices. Extension costs are included of various seed multiplication and dissemination projects, the government extension system and NGOs, and investments by private seed companies.

R&D costs were calculated using historical data from NARS Bean Research Programs and Ministry of Agriculture reports and records. Collaborating scientists from each country collected data on governments funding of staff salaries, overheads, research and seed dissemination; and other funding received by bean program from development agencies. The CIAT Africa region office provided data on funding provided to each African NARS, pro-rated spending on CIAT headquarter staff supporting Africa research (Johnson, et al., 2003), and support provided to the CIAT Africa office, PABRA, ECABREN, and SABRN. Administrative and overhead costs were estimated at 20% of total R&D costs.

Other extension costs were estimated by doubling seed and other technology dissemination costs incurred by the NARS and CIAT. Annual R&D costs were adjusted for inflation to equivalent values at 2005 prices using consumer price indices obtained from National Statistics and the World Development Report (World Bank, 2005). Historical bean output data for each country was obtained from FAO and complemented with national statistics. Projections for the period 2006-2015 were made by estimating a moving average of the previous three years.

Net research benefits & Returns on investment

Net Research Benefits (NRB) for each year is calculated as Gross Research Benefits (GRB) minus R&D costs (C). The NRB is converted into present values for 2005 by compounding past values and discounting future values. A 20% real interest rate is estimated for each country basing on an average 10% interest rate for long term treasury bills and a 10% risk premium. A net present value (NPV) of R&D benefits is computed for each country, as well as a rate of return (ROR) to investment and internal rate of return (IRR). Sensitivity analysis is conducted by adjusting the research costs and yield increases.

Scenario analysis

Establishing causality and appropriately attributing benefits to an intervention (e.g. new bean technologies) are essential steps in accurately estimating impacts. Impact studies that estimate the value of 'upstream' research (e.g. germplasm conservation and breeding trials) often have tenuous links or confounding factors (e.g. competing initiatives or spillover effects). In contrast, this analysis estimates the value of bean research both 'upstream' and 'downstream' (e.g. targeting and dissemination). Therefore, the cause and effect relationship between PABRA R&D investments and impacts is relatively straightforward. In SSA, the use of farm inputs, especially fertilizers or irrigation, remains minimal. Furthermore, few organizations research and develop beans outside of PABRA.

Benefits attribution requires differentiating the effects of the new research technologies from the contribution of other (exogenous) factors. Major exogenous factors that affect supply are acreage expansion due to population growth, and yield declines due to various pests, diseases, drought and worsening soil fertility. The effect of acreage expansion is accounted in the analysis by applying the yield gain to historical production data.

The specification of 'with' and 'without' research scenarios isolated the R&D effects from other causes of observed impact. The 'with' R&D case corresponds to the observed supply and demand specification at bean industry levels over years with the new bean technologies in use as defined above.

For a crop often consumed at home, estimating the 'without R&D' scenario is not straightforward. Since supply and demand situations without R&D are not observable, they need to be derived by estimating the level of bean yields, prices, and quantity supplied if no new bean technologies were developed and disseminated. The bean 'without R&D' production level is derived by estimating the average yield of the most popular traditional varieties, multiplied by the historical bean acreage in each year. The supply and demand elasticities and all other factors are assumed the same in the 'with' and 'without' scenarios.

6. RESULTS

FARMERS REACHED AND ADOPTION

PABRA networks have been effective in reaching interested small farmers. A majority of farmers testing varieties have subsequently adopted them. The proportion of households that adopted is generally high (over 50%). Data extrapolation shows that 37 million farmers (5.3 million households) are growing new varieties. In terms of area planted, new varieties covered on average 49 percent of the total bean area planted. The lowest area is 31% for Uganda and highest is 68% for DRC (

Table 4).

Table 4. Adoption and beneficiary estimates

Location	Improved seed for at least one season (%)	Adoption rate* (% of households)	% of total bean area in new varieties in 2003-5	Estimated number of beneficiaries**	Estimated number of farm-household beneficiaries**
DRC	88	82	68	2,673,364	381,909
Malawi	61	55	46	5,068,250	724,036
Rwanda	74	64	43	4,847,360	692,480
Tanzania	86	81	56	11,495,520	1,642,217
Uganda	58	53	31	10,601,590	1,514,513
Average/Total	73.4	67.0	48.8	34,686,084	4,955,155

* Adopters are those farmers who grew improved varieties > 2 seasons

** The share of total population engaged in agriculture was obtained from FAOSTAT (www.fao.org). The adoption level was obtained from the impact surveys. The average farm household size was assumed to be 7 persons.

Results indicate considerable success in disseminating new varieties; however little has been achieved in disseminating bean management technologies. In five countries, over 50% of farmers had accessed and planted new varieties for at least one season.

Nevertheless, only 1% to 12% of farmers reported having been trained in use of bean management technologies.

CHANGES IN BEAN YIELD

Average bean yield increases differed per country. Analysis of survey data revealed yield gain estimates of each country for the period 1986-2005: DRC 35%, Malawi 32%, Tanzania 30%, Rwanda 29%, and Uganda 41%. Survey results indicate that yield improvements of new varieties is still limited, and confirms that production increases has partly been realized through acreage expansion.

Although some national-level bean yield improvements are modest, the effect of R&D is more significant when yield stabilizing effects are considered. This aspect of R&D impact is rarely considered, due to difficulty in measurement (Johnson and Klass, 2003; Mather, et al., 2003). Yield stabilizing effects have been particularly important in countries afflicted by severe land degradation and drought such as DR Congo, Malawi, and Rwanda. Differences from 1998 estimated yield gain (Johnson, et al. 2003) are attributable to distinct harvest periods considered.

NET ECONOMIC BENEFITS AND RETURNS TO INVESTMENT

This section presents the estimates of the net benefits to farmers and consumers from increased in bean yields. Analysis of survey data that increasing yields generated higher cost associated with increased labor for staking, harvesting and winnowing. No other additional inputs required to achieve the yield increases.

Table 5. Net reduction in marginal cost per ton due to new bean technologies

Country	Proportional yield increase	Proportional increase in input costs per Ha	Proportional increase in input cost per Ton	Net proportional reduction in cost per ton (k_t)
DR Congo	0.35	0.10	0.07	0.63
Malawi	0.30	0.12	0.09	0.51
Rwanda	0.30	0.15	0.12	0.48
Tanzania	0.30	0.09	0.07	0.53
Uganda	0.41	0.10	0.07	0.75

Bean prices are expected to decrease as a result of increase in bean supply following widespread adoption of improved technologies. This reduction in equilibrium bean market prices is predicted by converting the proportional decrease in cost of production per ton

(k_t) in year t into an equivalent reduction in bean price (Z_t). The proportional change in supply is the downward reduction in industry costs given by the difference between the without R&D price and the cost per additional ton of beans if they adopt the new technologies. In practice this is the margin made by farmers assuming they continue selling at the original price. The demand and supply elasticities in the formula account for the response by producers and consumers to price changes.

(Z_t) =
(Proportional Supply Shift year t) x {Supply Elasticity/(Demand Elasticity + Supply Elasticity)}

The price elasticity of supply is an estimate of the supply shift due to new technologies. This measure helps estimate the price change response to a as a result of increased bean output in a given year. An approximate 0.5 supply elasticity is used as recommended in literature (Pardey, et al., 1998).

Table 6. Estimated market prices reduction for beans at maximum adoption

	Supply Elasticity	Demand Elasticity	Proportional reduction in price
DR Congo	0.80	0.50	0.18
Malawi	0.80	0.50	0.14
Rwanda	0.80	0.50	0.11
Tanzania	0.80	0.50	0.29
Uganda	0.80	0.50	0.14

The investment in R&D by each country, CIAT and other partners is estimated at US$16 million. International research by CIAT accounted for approximately 56% of the costs, while NARS and other partners contributed 44% (

Table 7).

Table 7. Total investments in bean R&D, 1986-2015

Country	PV of Total National R&D Investment	PV of Total CIAT R&D Investment	Total R&D Costs (2005 USD)	Share of R&D Costs (%)
Uganda	1,706,410	1,517,024	3,223,434	20
Tanzania	1,869,433	1,897,090	3,766,523	23
DRC-Kivu	1,127,978	1,897,090	3,025,068	19
Rwanda	1,422,818	1,897,090	3,319,908	21
Malawi	948,545	1,897,090	2,845,635	18
TOTAL	7,075,184	9,105,384	16,180,568	100

From 1986-2015, the net benefit realized from the US$ 16 million bean investment is nearly $199 million with an average annual net benefit of $6.6 million (Table 8). The Average rate of return on investment was 41%. Individual country benefits range from an average of NPV US$0.95 to 2 million per annum. The estimated ROR indicate that the lowest return is 25% for Northern Tanzania, while the highest is 71% for investment in Uganda's bean R&D. The differences in NPV and ROR for the countries are largely accounted for by the bean acreage and the average yield gain for each country.

Table 8. Net Benefits and Rates of Return to Investments in Bean R&D, 1986-2015

Country	NPV (2005 US$)	IRR (%)	Average NPV/Year	ROR (%)
Uganda	68,312,482	60	2,277,083	71
Tanzania	28,356,702	90	945,223	25
DRC	36,625,509	90	1,220,850	40
Rwanda	33,629,692	111	1,120,990	34
Malawi	31,695,834	56	1,056,528	37
Total/Average	198,620,219	81	6,620,674	41

The internal rates of return similarly indicate that investments in bean R&D were attractive and robust despite high market interest rates (20%). Compared to similar empirical studies of other crops in Africa (The returns to bean technologies are nearly equal to the average of other estimates of agriculture R&D. A meta-analysis of the returns to agricultural R&D revealed annual rates of return average 73 % overall: with ROR of 88 % for research only, and 45% ROR for research and extension (Alston, et al., 1998).

Table 9), the results indicate that investments in bean R&D generate more benefits to society than many other staple and cash crops in the region. The returns to bean technologies are nearly equal to the average of other estimates of agriculture R&D. A meta-analysis of the returns to agricultural R&D revealed annual rates of return average 73 % overall: with ROR of 88 % for research only, and 45% ROR for research and extension (Alston, et al., 1998).

Table 9. Estimates of Rates of Return to Agricultural R&D Investments

Country	Source	Commodity and period	Empirical estimates
IRR			
Uganda	Laker-Ojok (1994)	Maize	27%
		Groundnuts	23%
		Sesame	27%
Uganda	Wessler et al., (1999)	Maize	34%
		Beans	45%
		Cassava	44%
		Bananas	15%
ROR			
Africa	Evenson, 1987	Maize & staple crops	30-40%
Africa	Norgaard, 1988	Cassava, 1977-2003	149%
Africa (10 countries)	Aghib and Lownberg-DeBoer, undated	Sorghum, 1985-2009	58%
East Africa	Ewell, 1992	Potato, 1978-1991	91%
Kenya	Karanja, 1996	Maize, 1955-88	53-61%
Kenya	Makanda and Oehmke, 1996	wheat, 1921-1990	0-12%
Kenya	Akgnungor, et al., 1996	wheat, 1921-1990	14-30%
Malawi	Smale & Heisey, 1994	Maize, 1957-1992	4-7%
Namibia	Anandajayasekeram, et al.., 1996	Millet, 1988-99	11%
South Africa	Khatri, Thirtle and van Zyl, 1995	aggregate agriculture	44%
Sudan	Ahmed, Masters and Sanders, 1995	sorghum, 1979-1992	53-97%
Tanzania	Moshi et al., 1997	Maize, 1980-94	19%
Uganda	Laker-Ojok, 1994	Maize	27-58%
		Sunflower	10-66%
		Soybean 1985-1996	<0-20%
Zimbabwe	Kupfuma, 1994	Maize, 1932-1940	43.5%
Zimbabwe	Anandajayasekeram, et al., 1996	Sorghum, 1980-99	22%

Sensitivity analysis was conducted by varying the average yield gain, and total R&D costs. The yield gain was increased to 50% and 75% respectively; while total R&D costs were increased by 25%. The sensitivity analysis shows that the NPV, IRR, and ROR are relatively stable when subjected to adjustments in research and extension costs (

Table **10).**

Table 10. Effect of a 25% increase in R&D costs on Net Benefits and Rate of Return

Country	NPV of R&D Benefits (2005 US$)	IRR (%)	ROR (%)
Uganda	67,506,623	55	0.56
Tanzania North	27,813,083	78	0.20
DRC-Kivu	36,099,136	81	0.32
Rwanda	33,158,841	99	0.27
Malawi	31,292,248	52	0.29
TOTAL	195,869,930	73	0.33

R&D benefit estimates are more sensitive to changes in yield gains (Table 11). In a scenario with an additional 50% increase in yields, NPV benefits increase by over 60% with a similar increase in the ROR. Therefore, yield gains are an effective way to achieve sizeable increases in benefits to producers and consumers.

Table 11. Yield effects on Net Benefits and Rates of Return to Investments

Scenario/Country	NPV of R&D Benefits	IRR (%)	ROR (%)
With 50% Yield Increase			
Uganda	86,554,199	66	90
Tanzania North	53,082,025	126	47
DRC-Kivu	56,604,922	109	62
Rwanda	65,357,423	149	66
Malawi	60,305,438	69	71
TOTAL	321,904,007	104	67

An average increase in productivity of 6-8% would be sufficient for the R&D system to break even (Table 12). In other words, the investment performance in beans can likely withstand the effects of external shocks that cause wide variations in yields..

Table 12. Minimum yield gain required to achieve break-even investment performance

Country	Break-even yield gain
Uganda	7%
Tanzania North	6%
DRC-Kivu	6%
Rwanda	9%
Malawi	6%

SOCIAL BENEFITS OF NEW TECHNOLOGY ADOPTION

New bean varieties contribute to rural household incomes. Of bean household income in 2004-5, new varieties contributed 72% in DRC, 63% in Northern Tanzania, 44% in Malawi, 42% in Uganda, and 38% in Rwanda. Improved varieties have high marketability in all countries of the region. Farmers described numerous benefits resulting from the introduction of new bean technologies. Beans as an enterprise have wide-ranging impacts on rural livelihoods. Some benefits have been modest (such as new clothes), while others have been sufficient to enable farmers to make a radical shift and expand their livelihoods (e.g. opening a new business, ability to send children to secondary school, building a new house, etc.).

Nearly 60% of adopters report an improvement in food security as a result of improved varieties (Table 13). Despite the modest gains in per capita bean consumption, insights gained on the role of beans in child nutrition indicate a more critical role of beans in the diet. Analysis in Rwanda revealed that bean consumption by children under 6 years had a significant positive effect on their weight for age (Andima, 2005).

Table 13. Proportion of households reporting an improvement in food security

Location	% of adopters
DRC-Kivu	78
Malawi	61
Rwanda	57
Tanzania	46
Uganda	58
Mean	58.3

Source: Survey data.

Wealth-rankings provide insights into who were adopting the new varieties. Rankings, done by farmers themselves, indicated that the poor in their communities (and the very poor in the case of Rwanda) are just as likely to adopt the new bush beans as the more wealthy (Table 14). Hence, bean technologies are wealth-neutral - as little bias is apparent in terms of access to new seed.

Climbing beans can be considered less wealth neutral. Because the wealthy can afford to take risks with new technologies, such households can more easily use climbing bean varieties. Nevertheless, survey results also show high adoption among poorer farmers (Dymphina, 2005).

Table 14. Adoption levels of new bean varieties by wealth class (%)

Location	Poor	Medium	Rich
DRC-Kivu	80	82	91
Malawi	93	92	93
Rwanda*	Very poor 60 Poor 64	78	n/a
Tanzania	74	76	80
Uganda	54	50	50

* higher adoption of climbing beans in high altitude zones

New bean varieties produce gendered effects. Generally, in the PABRA region (with the exception of Ethiopia), women take lead decisions in bean production and selection. Nevertheless, the gendered effects of expanded new bean cultivation are both positive and negative. Expanded bean cultivation brought more income in the household and enabled more women to generate their own income. Nevertheless, additional bean production created challenges of requiring more labor - often of women.

Survey data shows that the use of bean harvests, home consumption or market sale, differs per country (Table 15). On average, farm households in Congo, Malawi and Rwanda consumer a higher percentage of their bean crop. Ethiopia and Tanzania more bean production is sold. In Uganda, similar amounts are consumed and sold. Ethiopian farm household consume the least (19%) while Rwandans consume the most (70%). The contribution of beans to the incomes of rural farmers is 24-47%, which indicates that beans are an important cash crop, especially for poor farmers.

Table 15. Mean percentage of household bean output consumed/sold

	% Consumed	% Sold	Contribution of beans to household income (%)
DRC-Kivu	62	23	37
Malawi	54	48	24
Rwanda	70	13	-
Tanzania	26	59	46
Uganda	39	38	-
Mean	45	42	39

Source: Survey data

Per capita bean consumption estimates indicate wide variation between countries but no significant difference between adopters and non-adopters of new varieties within countries (Table 16). Therefore, despite an improvement in food security, it appears that per capita consumption gains due to new varieties are small.

Table 16. Mean per capita daily bean consumption by adopters and non-adopters of new varieties

Per Capita Daily Bean Consumption (kg)	Adopter	Non-Adopter	F-test (p-value)
DR Congo	0.45	0.42	0.439
Malawi	0.22	0.23	0.488
Rwanda	0.43	0.40	0.259
Tanzania	0.13	0.13	0.677
Uganda	0.22	0.21	0.352

7. Discussion

At the time PABRA partners designed the *wider impact strategy* in 2001, impacts in the partner countries were geographically inconsistent. By 2005, adoption results show continued difference between countries and within countries (Table 17). Within-country differences in adoption are likely a result of wide variation in the effectiveness of NARS. Both low investment in seed dissemination and a lack of suitable improved varieties well-adapted to high stress drought conditions remain challenges.

Table 17. Minimum and maximum adoption rates within countries

Location	Minimum	Maximum
DRC-Kivu	37	98
Malawi	37	83
Rwanda	43	86
Tanzania	57	96
Uganda	10	91

Patterns of improved bean variety and cultivation practice adoption raise three concerns. One, high adoption occurred only in areas with explicit dissemination efforts. Major successes such as the 96 % adoption levels in northern Tanzania were achieved due to concerted team efforts for several years by NARS, CIAT, extension staff and farmers groups. In Uganda, adoption rates in districts where NGOs promoted seed dissemination and training in seed production are double those where such activities are lacking. Local seed/grain markets are an effective mechanism for new variety dissemination — only if seed has already been introduced.

Seed availability is a well known factor of successful technology dissemination. Evidence from country studies (Appendix 1) shows that adoption is highly correlated with the intensity of seed dissemination effort. Widespread adoption & utilization of bean varieties can be achieved only if: new varieties are highly demanded by both farmers and consumers, sufficient quantities of improved seed & agronomic knowledge are available to farmers; and the economic environment provides incentives for farmers to maximize the area planted.

Seed availability affects adoption patters because farmer use in seed markets is very low. Most farmers rely on home saved seed (Table 18). The data shows that 74% of farmers rely on home saved seed, while only 2% buy certified seed.

Table 18. Main sources of new variety seed by farmers (% of households)

Main source of seed	% of households
Home saved seed	74
Market/Shop (Not certified)	24
Certified seed seller	2
Government	2
NGOs	1
Other	1

Although rural seed systems can be improved with public support, a challenge lies in overcoming a market failure. Most poor farmers are unlikely to purchase expensive seed, unless the perceived profits from using certified seed outweigh the costs and risks associated with low and unpredictable farm gate prices and bean yields. Areas where CIAT, NARS, NGOs and other partners have assisted communities to establish community based seed production and dissemination activities exhibit some of the highest adoption rates. Consequently, PABRA member countries have dedicated additional resources to improve access to quality declared seed by creating capacity for seed production and marketing at community level, and training farmers in agro-enterprise skills.

A second concern is that only a small number of varieties are being adopted. Farmers commonly select 1 to 5 varieties out of the 10 to 20 varieties released per country. Cultivation of a narrow set of bean varieties could compromise future production stability in the face of biotic and abiotic stresses. Nevertheless, acceptance of such a small set suggests a significant 'untapped production potential' may exist. Promotion of a varied and larger set of new varieties could generate additional gains.

Third, although a majority of farmers have been exposed to new varieties, the potential acreage allocation has not been achieved. Although improved varieties have generally performed better than local varieties in countries, more impact can likely be realized by increasing acreage, and adopting better management practices.

Until recently, most varieties emphasized agro-ecological adaptation; however recent R&D efforts address market niches as well. Addressing both farmer and consumer preferences are a difficult challenge. Although research systems have continuously developed an increasing number of new varieties with diverse traits, the selection process of identifying the best varieties to test and cultivate can be difficult. Easily-used agronomic and market trait information of new varieties could help improve selection processes.

The impact analyses of DRC, Kenya and Tanzania all showed local markets as the primary source for new seeds. Many farmers, especially early adopters, become seed sellers. Market opportunities also exist at larger scale. International trade opportunities arise due to differences in supply and demand for beans, and capability to respond to production opportunities. Africa has a $95 million bean trade deficit, which implies that it imports beans. International trade between African countries also presents a market opportunity for many producers. For example, Rwanda, Burundi, Malawi and Kenya are regular net importers while Uganda, Ethiopia, and Tanzania are net bean exporters.

Without R&D, it can be argued that many African countries would have experienced bean harvest declines. Due to the resulting shortages, bean prices would have increased. Therefore, the 'without' R&D price estimate of beans is likely underestimated in the model and additional gains to consumers are likely.

The impact study was advanced despite no existing baseline data from a monitoring and evaluation (M&E) system. Few NARS have M&E systems, consistent M&E data on bean R&D. The establishment of regional coordination frameworks by PABRA and the sub-regional networks has presented an opportunity to consolidate and strengthen M&E. Given that CIAT and PABRA have established a regional M&E framework and set baselines, regular outcome and impact studies can be more easily advanced. The leadership and technical capacity established at the PABRA and ASARECA secretariats and CIAT's expertise are resources that can help harmonize national and regional M&E systems.

8. CONCLUSIONS

From 1985-2015, the net benefit from the US$16 million investment in SSA beans is approximately US$199 million. The average return to the total investment is 41% with substantial variation across countries (DRC-Kivu 40%, Malawi 37%, Rwanda 34%, Tanzania 25%, and Uganda 71%). The highest R&D benefits were realized in countries where annual bean output, acreage adoption, and yield gains were high. Both IRR and ROR of investments are comparable to results from studies of other food and cash crops. Despite the modest gains in harvest yields, the actual impact of research in Sub-Saharan Africa is likely much higher - due to the yield stabilizing effect of improved technologies.

Beans are often incorrectly considered as being only a subsistence staple crop and food. Despite this perception, farm households sell 42% of their bean output, on average. Beans contribute 24% - 47% of the income of a typical rural household. Many farmers indicated that the 'marketability' of new variety attributes is a priority for adoption. Market preferences influence variety choice due to the increasing bean trade in both domestic and export markets.

Cultivating beans are typically a wealth-neutral agricultural activity. Farmers in several countries, particularly Rwanda, reported that poor or very poor members of the community were as likely to adopt the new climbing varieties as wealthier farmers. Many adopters are women, who have seen their incomes rise substantially. To reduce the risk that men will try to appropriate the income gains by taking over what is traditionally a women's crop, PABRA has sought to build the capacity of women's groups and associated service providers in starting and running agro-enterprises. Other social benefits realized by participating bean farmers include exposure to new services providers (credit and input supplies) as well as new information on health and nutrition.

As part of the HarvestPlus initiative, PABRA researchers are continuing to develop biofortified beans with a focus on increasing the concentrations of iron and zinc in the grain of agronomically-superior varieties. Efforts to enhance the contribution of beans, particularly for those affected by the continuing spread of HIV/AIDS, require coordination with organizations outside the agricultural sectors. Besides developing and disseminating new nutritionally-rich varieties, promotional campaigns will need to involve community-based health and nutrition workers.

Beans are vital to Africa's struggle and start moving towards the Millennium Development Goal targets, such as halving hunger and poverty by 2015. PABRA's focus on seed-based technologies has been effective. Plant breeding, as the source of new varieties will continue to be a key activity. Since new threats constantly arise, the fight against pests and diseases must intensify and broaden. Besides bean root rot, other critical diseases that need attention include angular leaf spot, anthracnose, leaf rust, common bacterial blight and bean mosaic virus. Priority pests include aphids, bean stem maggots and cutworms. In addition there will be continued focus on low soil fertility and drought. Selection and breeding for resistance or tolerance will, as now, be combined with IPDM approaches that maximize the gains to farmer and ecosystem health. Additional bean production increases will require developing and scaling up dissemination of high yielding stress-adapted varieties and remain a key R&D priority in Sub-Saharan Africa.

REFERENCES

Allen, D.J, and O.T.Edje. 1990. Common bean in African farming systems. In: J.B. Smithson (Ed). Workshop proceedings, *Bean Research* volume 5. CIAT Africa Workshop series No.12, pp20 -32

Allen, D.J., M.J. Dessert, P. Trutman, J. Voss. 1989. Common beans in Africa and their constraints. In: H.F. Schwartz and M.A. Pastor Corrales {Eds.}. *Bean Production Problems in the Tropics.* CIAT, Cali, Colombia, pp9 -31

Alston, J., G. Norton, P. Pardey. 1998. Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. Ithaca, NY: Cornell University Press.

Alston, Julian, Michele C. Marra, Philip G. Pardey, T. J. Wyatt. 1998. *Research Returns Redux: A Meta-Analysis of the Returns to Agricultural R&D.* EPTS Discussion Paper No. 38. International Food Policy Research Institute, Washington, D.C.

Ampofo, J.K., 1998. Monitoring and evaluation of IPM development with small-scale farmers in Tanzania. In: A.L.Jone {Ed}. *CIAT Bean Project Annual Report, 1998,* pp175 - 176

Anandajayasekeram, P. 2004. Monitoring, Evaluation and Impact assessment of R&D investments in Agriculture, workshop , ISNAR, Nov 1-12 Addis Ababa, 2004.

Anandajayasekeram, P., and D. Martella. 1996. A training manual on research and Development evaluation and impact assessment of the investment in agricultural and natural resources research. *Journal of Agricultural Economics and Development,* 1(1).

Andima D., Kalyebara R., 2005. Longitudinal Impact Assessment Of Bush Bean (*Phaseolus Vulgaris*) Varieties on The Livelihoods of Rural Communities in Eastern Uganda. Pan-Africa Bean Research Network, Occasional Paper Series, No.---, CIAT, Kampala, Uganda (In Press).

Bosch, C.H. 1992. Evolution of research in Kagera region, Tanzania, 1988 –1992. In: D.J. Allen {Ed}. Workshop proceedings, CIAT African Workshop Series, No27, pp 13-20

CIAT. 1995. Bean program annual report. Working document. No. 163. Pp 328

David, Soniia and Louise Sperling. 1999. Improving technology delivery mechanisms: Lessons from bean seed systems research in eastern and central Africa. *Agriculture and Human Values.* 16: 381-388.

David, Soniia, L.Mukandala and J.Mafuru. 1998. Adoption of Lyamungu 90 in Bukoba district, north-west Tanzania. In: Jones (Ed). Bean projects IP-1 and IP -2 Annual Report. p. 179 -180.

David, Soniia, 1997. Dissemination and adoption of new technology: A review of experiences in bean research in Eastern and Central Africa, 1992-1996, Network on Bean Research in Africa, Occasional Publication Series, No. 21, CIAT, Kampala, Uganda.

David, Soniia, L. Mukandala and J. Mafuru, 2002. Seed availability, an ignored factor in crop varietal adoption studies: a case study of beans in Tanzania. CIAT, Kampala (Unpublished).

David, Soniia, Roger Kikby and Sarah Kasozi, 2000. Assessing the Impact of bush bean varieties on poverty reduction in Sub-Saharan Africa: Evidence from Uganda. Network on Bean Research in Africa, Occasional Publication Series, No. 31, CIAT, Kampala, Uganda.

De Steenhuijsen Piters, C.B. 1995. Diversity of fields and farmers: Explaining yield variations in northern Cameroon. Ph.D. thesis. Wageningen Agric. Univ., Wageningen, the Netherlands

Due, M.J; Rugambisa J; Tilahum N; Schwartz R. [1985]. Beans (*Phaseolus vulgaris*) in the farming systems in Tanga Region, Tanzania 1985. Department of Rural Economy, Sokoine University of Agriculture; Morogoro, Tanzania. Technical Report No 16 pp53.

Edje, O.T, 1995. Bridging the research -farmer gap: experience with on-farm research on beans in Tanzania. Workshop proceedings. CIAT African Workshop Series, No31. pp 205 - 217.

Edje, O.T; J. Maimu; O.D. Mbuya; P. Ndakidemi; and C.S.Mushi [1989]. "Progress in on-farm research in the Usambara Mountains of Northern Tanzania" In: J.B. Smithson (Ed.). Proceeding of the first SADCC Regional Bean Research Workshop, Mbambane, Swaziland, 4-7 October, 1989. CIAT Africa workshop series no 6, SADCC/CIAT Program on beans in Southern Africa, Arusha, Tanzania.

Grisley, W, 1990. An overview of bean production in Sub-Saharan Africa. In: J.B. Smithson {Ed}. Workshop proceedings, Bean research Volume 5, pp9 - 19

Grisley, W. 1994. The bean revolution, *Ceres.* 149 (5) 27-30.

Hoogendijik M. and David Soniia. 1997. Bean production systems in Mbale district, Uganda with emphasis on varietal diversity and adoption of new climbing varieties. Network on Bean Research in Africa, Occasional Paper Series, No. 32, CIAT, Kampala, Uganda.

Horton D., P. Ballantyne, W. Peterson, B. Uribe, D. Gapasin and K. Sheridan, 1993. *Monitoring and Evaluation of Agricultural Research: A Sourcebook.* International Service for National Agricultural Research (ISNAR): The Hague, and CAB International: Wallingford.

Horton, D, E., 1990: Assessing the impact of international research: concepts and challenges. In Echeverria, R.G., ed. 1990. Methods for diagnosing research system constraints and assessing impact of agricultural research, Vol. II. Assessing impact of agricultural research, ISNAR, the Hague.

INERA, 2001, Rapport financier, division de finances, Centre de Mulungu, 2001. Division provincial de plan, 2000 : Rapport annuel 2000, Division provinciale de Plan Sud-Kivu

INERA, 1997, Rapport annuel du centre de Recherche, INERA MULUNGU, 1997

Johnson, N.L., D. Pachico, C. Wortmann. 2003. Impact of CIAT's Genetic Improvement Research on Beans. p 257-274 In: R. E. Evenson and D. Gollin. *Crop Variety Improvement and its effect on Productivity: The Impact of International Agriculture Research.* Wallingord: CABI.

Johnson, N.L.; Klass, J. 2003. The impact of crop improvement of rural poverty: An analysis of bean varieties to bean golden mosaic virus in Honduras. In: Mathur, S.; Pachico, D.H.; Jones, A.L. (eds.). *Agricultural research and poverty reduction: Some issues and evidence.* Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. p. 241-258. (CIAT publication no. 335).

Kamau, M and S. David, [1998]. A market survey to assess the adoption of Lyamungu 85 and Lyamungu 90 in Northern Tanzania. In: A.L. Jone {Ed}. CIAT Bean Project Annual report, 1998, pp180 - 181

Kamau, M.W, P. A. Ndakidemi and J. Maimu [2000]. A bean market survey in Arusha and Kilimanjaro regions of Tanzania: Comparison of production, trading and consumption of varieties. Survey report, Selian Agricultural Research Institute, March 2000.

Karel, A.K, B.J. Ndunguru, M. Price, S.H.Semnguruka and B.B.Singh (1981). Bean Production in Tanzania. In: Regional workshop on potential for field beans in Eastern Africa, Lilongwe Malwi 1980. Centro Internacional de Agricultura Tropical, Cali, Colombia, pp.123- 154

Kimani, Paul, Roland Chirwa, A. Namayanja, Capitolene Ruradama, Felicite, S. Gebeyehu, N. Mbikayi, Lodi Lama. 2008. Breeding Better Bean Varieties for African farmers: Achievements and Future directions. Presentation at the PABRA Stakeholders Workshop. 21-25 January. Kampala, Uganda.

Kweka, S. O, P. A. Ndakidemi, C.S. Mushi, E. Nkonya and S. David [1998]. Adoption of Lyamungu 85 variety in Hai, Moshi Rural and Mbulu districts of Northern Tanzania.Survey report. Selian Agricultural Research Institute, Arusha

Limbu Festus, 1999. Agricultural technology economic viability and poverty alleviation in Tanzania. Paper presented at the structural transformation policy workshop from 27-30th June 1999 at Serena Hotel - Nairobi , Kenya.

Macartney, J.C and D.R.W. Watson (1967). Beans. Tengeru Report No.89. Ministry of Agriculture, Tanzania

Mafuru, J. M; L. Maimu; Bosch, C.H, [1995]. The adoption and diffusion of Lyamungu 90 bean variety in Kagera region, Tanzania. CIAT Field Note No. 58 [SB327.M338]. pp16.

Mugabe, J. 1994. Research on Biofertilizers: Kenya, Zimbabwe and Tanzania. Research on Biofertilizers: Kenya, Zimbabwe and Tanzania. *Biotechnology and Development Monitor*, (18) p. 9-10.

Mather, D.L., R. Bernsten, J.C. Rosas, A. Viana Ruano, D. Escoto. 2003. The economic impact of bean disease resistance research in Honduras. Agricultural Economics. 29(3)343 - 352.

Mushi, C.S (1990). Progress in Bean Improvement in Tanzania. In: J.B.Smithson. Bean Research Volume 5. Progress in Improvement of Common Bean in Eastern and Southern Africa. CIAT Workshop Series No. 12.

Mushi, C.S, and O.T. Edje, 1989. The potential impact of Lyamyngu 85 in Northern Tanzania. In: Maeda and Nchimbi {Eds}. Workshop proceedings, Bean Research Volume 4, pp57 -61

Mushi,C.S. [1990]. Progress in bean improvement in Tanzania. In: J.B. Smithson {Ed}. Workshop Proceedings, Bean Research Volume 5, pp 43 - 54

Ndakidemi,P.A; C. S. Mushi and S. David [1995]. The adoption of Lyamungu 85 and Lyamungu 90 beans varieties among seed recipients in Lushoto district, Tanzania. Survey report, Selian Agricultural Research Institute, Arusha.

Ngulu, F.S, S.O. Kweka, S. Slumpa, J. Msakyi, C. Lyamchai, R. Ngatoluwa and J. Wickama [2002]. National Bean Research Programme Annual Progress Report. Selian Agricultural Research Institute, Arusha.

Nkonya, E. P.Ndakidemi, C. Mushi and D. Normman [1998]. Adoption and environmental impact of an improved bean variety in Northern Tanzania. A paper submitted for presentation at the AFSRE Symposium, Pretoria, South Africa, Nov. 30th - December 4th 1998

Odendo, Martin, David, Soniia, Otysula, Robin and Buruchara, Robin. November 2002. Impacts of Improved Bean Varieties in Western Kenya. Kenya Agricultural Research Institute (KARI) and CIAT

Oehmke, James F., 1992 : Technology impact and Agricultural transformation. Lessons learned from impact studies. Paper presented at the symposium on the impact of technology on agricultural transformation in Africa, october 14-16, 1992, Washington, DC

Phiri M.A.R, R. Chirwa, S. Kandoole and R. Tripp, 2000. Introducing New Bean Varieties With Small Seed Packs: Experience from Malawi. Network on Bean Research in Africa, Occasional Publication Series, No. 32, CIAT, Kampala, Uganda.

PNUD, 1994: Programme de relance du secteur Agricole des provinces du Sud et du Nord-Kivu, vol 2.

Chen, Shaohua and Martin Ravallion. 2008. The developing world is poorer than we thought, but no less successful in the fight against poverty. Policy Research Working Paper 4703. Development Research Group, World Bank. Washington DC

Sperling L., Urs Scheidegger, Robin Buruchara, P. Nyabyenda and S. Munyanesa, 1994. Intensifying Production Among Smallholder Farmers: The Impact of Climbing Beans in Rwanda. CIAT African Occasional Publication Series, No. 12, CIAT/RESAPAC, Butare, Rwanda.

Tchale Hardwick, 2001. Informal Cross-Border Trade: The Case of Beans in Eastern and Southern Africa - Implications on Bean Seed Multiplication, Dissemination, Entrepreneurship and Quality. In 'Proceedings: Bean Seed Workshop, Arusha, Tanzania January 12-14'; Bean/Cowpea Collaborative Research Support Program, East Africa. Cooperative Extension, Washington State University, http://eastafricacrsp.wsu.edu/

Wessler G.H., P.K. Ngategize, L. Aliguma, M. Mutetikka, Y. Baguma, R. Sabiiti, b. Tayebwa, and P. Karuhanga, 1999. Economic Assessment of Agricultural Research in Uganda. National Agricultural Research Organisation, Socio-Economics Working Paper No. 1, Entebbe, Uganda.

World Bank. 2007. *World Development Report 2008: Agriculture for Development.* Washington DC: The World Bank. 384 p.

Wortmann and Allen, 1994 : cité par Mbikayi in Characterization of Bean market in Eastern; DRCongo, in Towards the development of market-driven research framework, ECABEN draft, may 2000

Wortmann, C., R. Kirkby, C, Eledu, D. Allen. 1998. *Atlas of Common Bean Production in Africa.* Pan-Africa Bean Research Alliance.

Wortmann, C.S. and C. A. Eledu, 1999. Uganda's Agroecological Zones: A guide for planners and policy makers. Kampala, Uganda: Centro Internacional de Agricultura Tropical (CIAT).

APPENDICES

APPENDIX 1: LIST OF COUNTRY-SPECIFIC IMPACT REPORTS

Democratic Republic of Congo

Mumbeya, Paulin Njingulula, Tshitebwa, Musungayi and Kalyebara, Robert. Assessment of the Impact of Improved Bean R&D technologies in the Eastern D.R. Congo. Institut National pour l'Etude et la Recherche Agronomiques (INERA) in collaboration with ECABREN and PABRA.

Kenya

Odendo, Martin, David, Soniia, Otysula, Robin and Buruchara, Robin. November 2002. Impacts of Improved Bean Varieties in Western Kenya. Kenya Agricultural Research Institute (KARI) and CIAT.

Malawi

Kalyebara M. R., D. Andima, S. P. Kazombo, and R. Chirwa; 2007. Farm-level Impacts of Improved Bean Technologies in Malawi. Occasional Publication Series No. ---. Pan African Bean Research Alliance, CIAT Africa Region, Kampala, Uganda.

Andima, Dymphina. January 2004. Social Impact Assessment of Bush Bean Varieties (*Phaseolus vulgaris* L.) on the Livelihoods of Rural Communities in Malawi.

Rwanda

Mugabo, R. Josaphat and Kalyebara, Robert. Impact of Improved Bean Varieties in Rwanda., April 2006. Institut des Sciences Agronomiques du Rwanda (ISAR), in collaboration with PABRA and CIAT.

Andima, Dymphina. January 2005. Social Impact Assessment of Improved Climbing Bean Varieties in Rwanda.

Uganda

Kalyebara, Robert, Mugisha Kassozi Sarah, Andima Dymphina and Nasirumbi, Losira. July 2006. The Impact of Improved Bush Bean Varieties and Management Technologies in Uganda. National Agricultural Research Organisation, NAARI, PABRA, CIAT

Andima, Dymphina June 2005. Longitudinal Impact Assessment of Bush Beans (*Phaseolus vulgaris*) Varieties on the Livelihoods of the Rural Communities: The Case of Uganda.

Tanzania

Xavery, Peter, Kalyebara, Robert, Kasambala, Cindi, Ngulu, Festo. May 2005. The Impact of Improved Bean Varieties in Northern Tanzania. Selian Agricultural Research Institute (SARI) Tanzania, in collaboration with PABRA and CIAT.

Appendix 2: Average farm gate prices for local and improved varieties (US $/Kg)

	Local variety	Improved variety	Average
DRC	0.34	0.47	0.40
Malawi	0.50	0.44	0.47
Uganda	0.19	0.17	0.18
Rwanda	0.21	0.21	0.21
Tanzania North	0.22	0.23	0.23
Average	0.29	0.31	0.30

GENDER	TYPE_TRAINING	total
F	TESIS MS	6
F	TESIS PHD	14
F	ESTUDIANTE MS	1
F	ESTUDIANTE PHD	3
F	ESPECIALIZACION	38
F	CURSO ESPECIALIZAD	40
M	TESIS MS	7
M	TESIS PHD	12
M	ESTUDIANTE MS	3
M	ESPECIALIZACION	50
M	CURSO ESPECIALIZAD	51