ECONOMIC IMPACT EVALUATION OF THE ICRISAT JEWELS

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International Crops Research Institute for the Semi-Arid Tropics

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ECONOMIC IMPACT EVALUATION OF THE ICRISAT JEWELS

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KEY MESSAGE

This ex-post impact assessment of the Jewels of ICRISAT shows a return on investment of $43 for every dollar invested, with an internal rate of return of 41%. By including innovations that have been developed for extended periods, such as wilt-resistant pigeonpea, the average return on investment is $70 per dollar invested. Note:

i. These figures are based on ten of the most successful initiatives of ICRISAT and do not represent all of ICRISAT's investments over its more than four decades of work.

ii. Where complete data was not available, the most conservative estimates were applied. Currently a more rigorous and detailed impact assessment is being undertaken for each jewel and the ROIs will be revised accordingly.

Message from the
DIRECTOR GENERAL

Since its inception in 1972, ICRISAT has been engaged in international agricultural research to empower over 800 million smallholder farmers across the semi-arid regions of the world. In these 42 years, through its innovations and breakthroughs, which we now call the *Jewels of ICRISAT,* the institute has been working with a diverse range of partners in Africa and Asia to help smallholder farmers overcome poverty, hunger and a degraded environment through better agriculture. This publication on the Jewels of ICRISAT addresses a range of strategic priorities including food sufficiency, poverty alleviation, sustainable resource management, and women's empowerment among others. However, these efforts could not be possible without *visionary investors* such as governments, development banks, foundations, charitable organizations, and private sector companies, who recognize that elimination of poverty is the key to a peaceful world with food security and prosperity for all, and extended their support to ICRISAT.

This report, *Economic Impact Evaluation of the ICRISAT Jewels*, is a milestone among ICRISAT publications. This volume records the impacts of the Jewels and presents detailed estimates of the economic rates of return to investment for a set of ICRISAT's Jewels.

This **ex post impact assessment** of the Jewels of ICRISAT shows a **return on investment of $43** for every dollar invested, with an **internal rate of return of 41%**. By including innovations that have been developed for extended periods, such as wilt-resistant pigeonpea, the **average return on investment is $70** per dollar invested. However, it is important to recognize that the impact of **only ten of the most successful initiatives** of ICRISAT were evaluated during this exercise and it does not represent all of ICRISAT's investments over its more than four decades of work.

Although the report does not capture the full breadth of ICRISAT's activities, it does provide an overall assessment of the important activities that constitute ICRISAT's portfolio. I am pleased to note here that the high returns to investment indicate that the Jewels of ICRISAT have been strikingly effective in fulfilling ICRISAT's mission. The strategic public, private and civil society partners we have worked with the world over have played an indispensable part in this achievement.

I thank our partners and visionary investors for their unwavering support to our cause. ICRISAT will continue to work with them to bring about pro-poor growth and inclusive market-oriented development.

William D. Dar

Executive Summary

Agricultural research and development (R&D) can address a range of strategic priorities including food sufficiency, poverty alleviation, sustainable resource management, and women's empowerment among others. Given the diverse forms of impact possible, measuring the full impact of a given technology is likely to require a multidimensional approach. While the goals of R&D are many, the return on investment constitutes a basic gauge for evaluation. Determining the value of crop production generated per dollar invested in developing a crop technology can indicate whether the investment was warranted and the scale of the pay-off to successful programs. This analysis, therefore, presents both baseline and pessimistic results for ICRISAT crop variety initiatives such as Drought Tolerant Groundnuts in Anantapur District, India (1991-2020), Malawi (1983-2013) and Nigeria (1996-2013), Extra-Early Pearl Millet Hybrid in Northwestern India (1999-2013), Pigeonpea in Northern Tanzania (1993-2022), Wilt Resistant Pigeonpea in India (1975-2013), fertilizer microdosing in Zimbabwe (1999-2013) and Niger (1994-2013), HPRC Pearl Millet in India and HPRC Sorghum Hybrids in India. The report also looks at an assessment of return on investment on Watershed Management in Lucheba, China (2003-2013). For projects that have not yet matured, an ex ante analysis is carried out for the following: Guinea-Race Sorghum Hybrids in Mali (2000-2024), Sweet Sorghum in India (2002-2020) and Pigeonpea Genome in India (2010-2024).

The analysis relies on previously reported data to estimate the economic impact of specific initiatives, using an economic surplus approach, implemented through the Dynamic Research EvaluAtion for Management (DREAM) model. While attempting to be conservative in calculating benefits, this analysis focuses exclusively on producers in specific locations, ignoring spillover effects through which producers and consumers in other areas may have been affected by the technology. To the extent that spillovers have occurred, this analysis understates the total benefits of the technologies examined (but may exaggerate the benefits to the specific producers considered, if the spillovers result in price effects).

Despite the shortcoming of existing data, baseline results represent a reasonable estimate of economic impact of ICRISAT's Jewels by showing a return on investment of $43 per dollar invested and an internal rate of return of 41%. By including wilt-resistant pigeonpea (which can be considered as an outlier due to its exceptionally large scale of adoption and its extended project period), the average return on investment for the projects assessed ex-post is $70 per dollar invested and an internal rate of return of 35%. Given the uncertainty in the measurement of various parameters aligned with exclusion of impacts of the Wilt Resistant Pigeonpea, pessimistic parameter values lead to return on investment values ranging from $4 to $50 per dollar invested and an average of $22 per dollar invested. Even under this extremely unlikely scenario, the average rate of return of $11 is substantial for all projects, excluding Wilt Resistant Pigeonpea. The overall internal rate of return under this pessimistic scenario is 42% and under highly pessimistic scenario is 32%. These indicate that even under highly conservative estimates of parameters, the Jewels of ICRISAT have each performed well.

These results are consistent with a comprehensive meta-analysis of rates of returns that concluded that in general investment in agricultural research and development has significant high payoffs to society. Elsewhere returns to investment in irrigation water management, integrated pest management in stored grain and rice productivity improvement projects have return on investment ranging between $17 and $177 per dollar invested. A recent assessment of rates of return to sorghum and pearl millet global research and development had an internal rate of return of about 60%, and for sorghum alone was even higher at 72% per year. Though it does not capture the full breadth of ICRISAT activities, this report does provide a uniform assessment of activities that constitute an important share of ICRISAT's portfolio.

01 Introduction

The analysis relies on previously reported data to estimate the economic impact of specific initiatives, using an economic surplus approach, implemented through the

Dynamic Research EvaluAtion for Management- DREAM model.

Agricultural research and development (R&D) can address a range of strategic priorities including food sufficiency, poverty alleviation, sustainable resource management, and women's empowerment among others. Given the diverse forms of impact possible, measuring the full impact of a given technology is likely to require a multidimensional approach. While the goals of R&D are many, the return on investment constitutes a basic gauge for evaluation. Determining the value of crop production generated per dollar invested in developing a crop technology can indicate whether the investment was warranted and the scale of the pay-off to successful programs. This analysis presents estimates of the economic rates of return to investment in a set of ICRISAT's Jewels whose benefits can be largely captured through measured effects on crop production.

The 16+ Jewels are a selection of ICRISAT's breakthrough innovations (ICRISAT 2012), and this analysis focuses on 10 projects that cut across the Institute's four Research Programs: Grain Legumes, Dryland Cereals, Resilient Dryland Systems, and Markets, Institutions and Policies. The analysis presents separate ex post analyses of the following crop technologies:

- Drought Tolerant Groundnuts in Anantapur District, India (1991-2020), Malawi (1983-2013), and Nigeria (1996-2013)
- Community-based Watershed Management in Lucheba, China (2003-2013)
- Extra-Early Pearl Millet Hybrid in Northwestern India (1999-2013)
- Pigeonpea in Northern Tanzania (1993-2022)
- Fusarium Wilt Resistant Pigeonpea in India (1975-2013)
- Fertilizer Microdosing in Zimbabwe (1999-2013) and Niger (1994-2013), and
- Hybrid Parents Research Consortium (HPRC) Pearl Millet and Sorghum in India (2000-2013).

Returns to three additional Jewels that have not yet matured sufficiently for ex post analysis are estimated ex ante. These technologies are:

- Guinea-Race Sorghum Hybrids, Mali (2000-2024),
- Sweet Sorghum, India (2002-2024),
- Pigeonpea Genome (2010-2024).

The analysis relies on previously reported data to estimate the economic impact of specific initiatives, using an economic surplus approach, implemented through the Dynamic Research EvaluAtion for Management (DREAM) model (Wood, You and Baitx 2001). These ten ICRISAT initiatives represent efforts to improve crops or crop production management, and therefore have impacts that can be measured through links to farm productivity. In many cases, these initiatives have been implemented in slightly different ways with different impacts across contexts. Thus, the study presents estimates of the rates of return on early maturing groundnuts in three different countries, fertilizer microdosing in two countries, and the HPRC impacts for two crops.

There are additional ICRISAT Jewels that have generated large social impacts that could not be assessed using the methods applied here. Three Jewels, the Genebank (Genetic Resources for Food Security), the Village Level Studies/ Village Dynamics Surveys, and the Open Access Repository have generated direct benefits and supported the success of other ICRISAT

activities, including the other Jewels. No attempt has been made to directly assess the return on investment to these initiatives. However, one can take the average return on the activities they have supported as an approximation of their rate of return through indirect contributions to these activities.

Though it does not capture the full breadth of ICRISAT activities, this report does provide an overall assessment of activities that constitute an important share of ICRISAT's portfolio. The analysis does not comprehensively quantify all possible benefits, such as benefits from new knowledge and capacity building, and social, human health and environmental benefits. This is similar to other impact assessments of agricultural research. The existing literature has demonstrated high returns on investments. Investments by the Australian Centre for International Agricultural Research (ACIAR) in irrigation water management in Vietnam, integrated pest management in stored grain in Philippines and rice yields in Laos yielded benefit-cost ratio of 17:1, 177:1 and 145:1, respectively (Lindner, McLeod and Mullen 2013). A recent assessment of rates of return to global research on sorghum and pearl millet by Zereyesus and Dalton (2013) had an internal rate of return of about 60%, and for sorghum about 72% per year. Applying a 5% discount rate, Bervejillo et al. (2011) finds returns of $48 to $90 per dollar invested in public agricultural research in Uruguay. These results are consistent with a comprehensive meta-analysis of rates of returns by Alston et al. (2000) that concludes that, in general, investment in agricultural research and development has significantly high payoffs to the society.

02 General Approach

This analysis focuses exclusively on producers in specific locations, ignoring spillover effects through which producers and consumers in other areas may have been affected by the technology ■

Given data limitations, a number of simplifying assumptions have been made to facilitate this analysis. As a result, many potential effects are not captured here. The general approach focuses on estimating gains to producers in specific countries or regions through improved productivity in the form of decreased production costs per ton. All estimations of economic surplus treat these cases as "small open economies" meaning that the changes in production following the introduction of the new technology do not influence market prices and therefore do not affect consumers. Rather, for small country exporters (such as Malawi for groundnuts) or importers (Nigeria for groundnuts), international markets drive local prices and are not influenced by local changes in production. While India may present neither a small nor an open economy with respect to the crops affected (eg, pearl millet), the regions affected by the technology may be treated as price takers within India. Specifically, the analysis assumes, for example, that changes in the volume of groundnut production in Anantapur district that are attributable to the introduction of early maturing/drought tolerant varieties do not influence the groundnut price nationally. To the extent that technologies do, in fact, result in lower consumer prices, this analysis overstates the producer benefit and understates the consumer benefits with the overall impact of underestimating aggregate benefits.

This analysis focuses exclusively on producers in specific locations, ignoring spillover effects through which producers and consumers in other areas may have been affected by the technology. In many cases, technologies have been adopted outside of the areas in which they were initially introduced. As a result, the technologies have had impact on more producers than this analysis considers. These spillover effects may also imply large country impacts with feedbacks on producers in the targeted locations that are not captured in these estimations. To the extent that spillovers have occurred, this analysis understates the total benefits of the technologies examined, but may exaggerate the benefits to the specific producers considered, if the spillovers result in price effects.

Estimated benefits to producers are compared with the costs of research (and extension undertaken by ICRISAT) to estimate a return to the research investment. Once the return on each investment is calculated, an overall rate of return on these Jewels is calculated. Details of this method of estimating returns to agricultural investment are provided in Alston et al. (1998). Alston et al. (1998) also provides detailed discussion of spillover and consumer impacts that are not treated in this analysis.

The approach to estimating benefits amounts to an effort to calculate the flow of additional net revenues (or savings if the crop is not sold) attributable to the new technology. Reported benefits are an estimate of the benefits enjoyed by the smallholder farmers adopting the technologies under study. The data required for this estimation are the prices for the product over the period of analysis; the impact of the technology on production costs per hectare and yield per hectare; the elasticity of supply; the adoption rate; and the lag between product release and maximum adoption (followed by disadoption if relevant). The calculated benefits are then compared to the investment costs,

using data on the research and extension expenditures, the lag between expenditure and adoption, and a discount rate. Many of the parameter values evolve through time. The DREAM model is applied by fitting trend lines to the actual data, rather than directly using the observed data, such as annual prices. This process smooths the annual variation in impacts and facilitates sensitivity analysis.

Basic parameters for calculating economic surplus are provided in Tables 1 and 2. These parameters are based on published reports and data provided by ICRISAT scientists. In some cases, information is from expert opinion rather than published reports. Time frames for analysis are derived from earlier studies, but may be truncated or extended to provide for ex post analysis. In most cases an average output price is applied based on the observed average over the period of analysis. Where there is a pronounced upward or downward trend in prices, a price trend is modeled by applying an average annual growth rate to the base year price. In each study values are presented in terms of constant (2010) US dollars in the base year.

The more price sensitive producers are, the greater will be the increase in production following a reduction in the costs of producing a given volume of output. This sensitivity is captured in the supply elasticity parameter. Although supply elasticities are not known with certainty, they have only a small impact on estimated economic surplus. Model results using elasticities set at 50% of the initial level are presented in a sensitivity analysis.

The R&D lag represents the number of years between the initial investment in research and development and the first adoption of the variety or technology by farmers. Since all values are discounted back to the time of the initial investment, the longer the lag, the greater the eventual benefits must be to compensate for the discounting of benefits that occur farther in the future.

The productivity impact is measured through the K-shift, which captures the combined effect of the adoption of a new technology on quantity produced per hectare and the costs of production per hectare. In all cases, adoption of a new variety raised yields and altered the costs per hectare, reducing the costs per ton produced. The aggregate impact of technology depends on how widely, quickly, and persistently it is adopted. The ceiling adoption rate of all technologies is given in Tables 1 and 2. Adoption itself is assumed to follow a sigmoid pattern over time, beginning at the end of the R&D lag and reaching its maximum at the end of the adoption lag. In one case, the technology is being disadopted after an extended period of use at the maximum rate. This disadoption is captured in the DREAM model when relevant.

Impact estimates tend to be highly sensitive to the estimated K-shift and adoption rates, as well as the initial price and output levels. While price and quantities can be measured with a high degree of confidence, the K-shift and the adoption rates are measured subject to error. Estimated productivity changes are particularly problematic as there is an inherent challenge of selection bias. Since early adopters of a new variety tend to be innovative farmers, yield comparisons between adopters and non-adopters can confound the effects of the variety with unobserved or unmeasurable characteristics of adopting farmers. A number of methods have been developed recently to address this problem. The specific method used in each case study is explained in section 3.

The time frame selected for analysis can have substantial impact on the measured return on investment. To capture the full benefits of a technology, the flow of benefits would be measured from initial release, through maximum adoption, sustained use, and on to either disadoption or a point in the distant future at which discounting makes the present value of benefits negligible. Rather than attempting to capture the full life cycle of the technologies, this study sets a time frame for each technology that begins with the initial investment expenditure and ends at either the present time (2013) or the projected time of maximum adoption, if maximum adoption has not yet been reached. This approach reflects an effort to refrain from calculating benefits that have not yet been realized. However, the time frames used implies that in most cases the analysis will significantly understate the likely benefits of adoption. Moreover, since the share of the life span covered for each technology differs, the selection of time frames used here has a differential impact across technologies. The stream of likely benefits for some technologies (eg, fertilizer microdosing) has been severely truncated, while that of others (eg, wilt resistant pigeonpea) is almost fully captured. In general, the timeframes chosen are conservative, leading to an underestimation of full benefits and therefore of the return on investment.

In many cases, ICRISAT enjoyed support of partners in its research efforts. Such partners include other CGIAR centers, national governments, NGOs and private sector agencies. In cases where such contributions have been especially substantial, as in HPRC sorghum and fertilizer microdosing, the adoption rate is adjusted downward to attribute only a share of adoption to ICRISAT. In other cases, there is no specific adjustment for the impact of partners' contributions. The rates of return indicated here are a reflection of joint efforts of ICRISAT and these partners.

A number of assumptions and simplifications have been made to enable the calculations presented here. In general, the analysis has attempted to be conservative in calculating benefits. For example, the value of by-products is not included in the analysis nor is the value of reduced variability in production, which is often a significant benefit to drought tolerant and early maturing varieties. The selection of time frames and the exclusion of spillover effects and large country effects also contribute to conservative estimates of total benefits. While the estimates presented here are structurally conservative, the uncertainty about parameter values is such that sensitivity analysis is necessary. In a "pessimistic" scenario the productivity effect (K-shift) and supply elasticity are set at one half of their baseline levels. In a highly (and unrealistically) pessimistic scenario the K-shift, supply elasticity and adoption rate are all set at one half of the baseline levels.

Rates of return are calculated by comparing the present value of costs with the present value of benefits. The Net Present Value (NPV) is simply the difference between the present value of costs and the present value of benefits. Two specific indicators of rate of return are presented. The internal rate of return (IRR) is the annual discount rate on costs and returns that would imply an NPV of zero. Since benefits emerge after the investment cost, a higher discount rate will reduce the present value of benefits more than the present value of costs. Thus at a sufficiently high discount rate, the NPV will be zero. This rate, the IRR, can be considered an annual rate of return on the investment.

The second measure of return is the return on investment (ROI). The ROI is simply the ratio of the present value of benefits to the present value of costs. Projects with high IRR values (greater than the actual discount rate) will have a NPV greater than zero and a ROI greater than one. The IRR and the ROI can lead to different rankings across projects, particularly when the projects have different durations. If there are two projects with the same annual internal rate of return and the same costs, the one that has a longer duration of benefits will have the higher ROI, simply because benefits have accumulated over a longer time period.

Each of the Jewels analyzed here is an example of ICRISAT initiative, but none of them were pursued by ICRISAT in isolation. In each case ICRISAT had strategic partners whose contributions were key to the success of the initiative. Those partners are acknowledged as being critical to the outcomes described here and are listed in Appendix A.

03 Implementation by Case

This section gives a case by case analysis of how the study was implemented for each of the jewels.

3.1 Drought Tolerant Groundnut in Anantapur District, Andhra Pradesh, India

Through the introduction of drought tolerant groundnuts, smallholder farmers in Andhra Pradesh, India are seeing higher, more reliable yields and greater incomes than could be attained with previously used varieties. Data for the Drought Tolerant Groundnuts, Anantapur case are taken from Birthal et al. (2011). The analysis is structured as a comparison of groundnut variety ICGV 91114 with TMV 2 (that was released 60 years ago, but still cultivated by farmers). The new variety, ICG 91114 has farmer preferred traits; high yield, early maturing (90-95 days in rainy season), tolerant to mid-season and end season drought, high oil and protein content; and good digestibility and palatability of haulms as fodder for livestock. ICG 91114 was released in 2006. Economically Anantapur is treated as a small open economy, accounting for 10% to 15% of groundnut production within the Indian national economy. Technical coefficients on yield effects, cost effects and adoption rates are taken directly from Birthal et al. (2011), which uses data from a farm survey. Costs of investment in research and extension are based on expert opinion and reported in 2010 real dollars. Investment costs are taken from 1991, when the variety was evaluated in on-station trials. The variety was first released in 2006 and has seen rapidly rising adoption, but has not yet reached the projected adoption rate of 35%.

Table 1. Parameters Used in Economic Surplus Analysis.

Parameter	Drought Tolerant Groundnut			Extra Early Pearl Millet Hybrid in Northwestern India	Improved Pigeonpea in Northern Tanzania	Fusarium Wilt Resistant Pigeonpea (Maruti) in India
	Anantapur District, India	Malawi	Nigeria			
Time frame	1991-2020	1983-2013	1996-2013	1999-2013	1993-2022	1975-2013
Discount rate	5%	5%	5%	5%	5%	5%
Exogenous price trend	0%	0%	0%	1%	0.5%	1%
Price (US$/ton)[a]	$700	$470	$600	$200	$198	$300
Production in base year (tons)	540,000	140,000	325,000	2,500,000	19,800	650,000
Elasticity of supply	0.7	0.7	0.6	0.25	1	0.2
R&D lag	15 years	7 years	7 years	7 years	13 years	12 years
Change in cost/ha	5%	11%	10%	-11%	-12%	-9%
Change in tons/ha	22.8%	28.74%	52%	40%	41%	55%
K- shift	18.73%	20.20%	45.42%	47.85	49.71%	60.81%
Adoption lag	15 years	12 years	11 years	8 years	7 years	8 years
Maximum adoption	35%	40%	30%	27%	56%	60%[b]
PV of costs to base year[a]	971	346	US$ 1,561,010	US$ 3,636,430	US$ 700,860	US$ 4,438,050

a. US dollar values have been adjusted to constant 2010 levels based on the US GDP deflator.

b. Disadoption over 30 years after 10 years at maximum.

Table 2. Parameters Used in Economic Surplus Analysis.

Parameter	Fertilizer Microdosing		HPRC		Guinea-Race Sorghum Hybrids In Mali (ex ante)	Sweet Sorghum in India (ex ante)	Pigeonpea Genome in India (ex ante)
	Maize in Zimbabwe	Pearl Millet in Niger	Pearl Millet Hybrids in India	Sorghum Hybrids in India			
Time frame	1999-2013	1994-2013	2000-2013	2000-2013	2000-2024	2002-2024	2010-2024
Discount rate	5%	5%	5%	5%	5%	5%	5%
Exogenous price/growth trend	0%	0%	0.75%	-1.0%/-0.25%	0%	0%	0.5%
Price ($/ton)in base year[a]	$250	$200	$190	$175	$190	$200	$400
Production in base year (tons)	706,600	1,250,000	6,750,000	3,500,000	750,000	500,000	2,000,000
Elasticity of supply	0.15	0.15	0.60	0.5	0.5	0.6	0.5
R&D lag	5 years	7 years	6 years	6 years	10 years	10 years	10 years
Change in cost/ha	5%	N/A	N/A	N/A	-20%	N/A	-10%
Change in tons/ha	75%	50%	0.75%[b]	0.66%[b]	31%	45%	30%
K- shift	72.14%	50%	0.75%[b]	0.66%[b]	46.27%	45%	37.69%
Adoption lag	4 years	10 years	1 year	1 year	15 years	14 years	12 years
Maximum adoption	30%	27%	25.5%[c]	40%[d]	30%	40%	10%
NPV of costs to base year[a]	US$ 2,674,970	US$ 3,000,000	US$ 2,062,550	US$ 1,559,040	US$ 1,020,470	$1,950,000	$1,352,280

a. US dollars values have been adjusted to constant 2010 levels based on the US GDP deflator

b. Per year, cumulative

c. ICRISAT share at the HPRC

d. Share of rainy season production

3.2 Drought Tolerant Groundnuts in Malawi

The ICGV-SM 90704 groundnut variety has been released in four countries of sub-Saharan Africa to address the need for drought tolerance. Data for the Drought Tolerant Groundnuts, Malawi case were from an earlier impact analysis of groundnut work in Malawi, Tanzania, Zambia and Uganda using the ACIAR Economic Impact Model (Lubulwa and McMeniman 1999). Since the ACIAR model is structurally similar to the DREAM model, data from that study could be applied in the DREAM framework. Values of technical parameters such as cost and yield effects were taken directly from the original analysis. The costs of the investment across the four countries were not disaggregated in the earlier study. In this analysis, those costs were distributed by share of production, implying that 75% of the reported research and extension investment budget was applied to Malawi. Calculations presented here assume that dollar values in the earlier work were reported in nominal terms. Values were converted into 2010 US dollars using the US GDP deflator and discounted to the base year, 1983. The methods for measuring the yield and cost effects are not documented in the source material. Based on expert opinion, Simtowe and Mausch (2012) report a somewhat higher adoption rate (58%) than is used in this analysis.

3.3 Drought Tolerant Groundnuts in Nigeria

Data for the Drought Tolerant Groundnuts, Nigeria come from Ndjeunga et al. (2012) and from data compiled and provided by ICRISAT directly. These two sources suggested divergent levels of adoption and yield and costs impacts. The ICRISAT data was the only source of cost information, which was provided in constant (2010) US dollars. Data from ICRISAT provide for direct comparison of yields and costs for adopters and non-adopters as well as direct measurement of the adoption level by year. To mitigate the effect of unobserved differences between adopters and non-adopters, the yield effect used here is the differential over the last five years of the ten year period for which data are available. The first five years of data are excluded on the grounds that the earliest adopters are likely to be exceptional farmers whose outcomes cannot be directly compared to non-adopters. After 5 years, the variety had become sufficiently widespread that the unobserved differences between adopters and non-adopters are likely to be less significant. Ndjeunga et al. (2012) applies a set of sophisticated econometric methods to estimate the productivity effects of the new varieties in a cross section of households. Their results yield a lower productivity effect than is suggested above and a lower adoption rate. The confidence interval on the point estimate from Ndjeunga et al. (2012), however, is wide. The results from Ndjeunga et al. (2012) (17.42% productivity effect and 25% adoption rate) are well above the levels used in the pessimistic scenarios that are calculated in the sensitivity analysis that follows.

3.4 Extra-Early Pearl Millet Hybrids in Northwestern India

ICRISAT's hybrid parents breeding program has supported pearl millet improvement programs with the national agricultural research systems. As a result of this effort, in 1990, CCS Haryana Agricultural University (CCSHAU) released the pearl millet hybrid, HHB 67, the earliest maturing and highly effective cultivar for raising millet yields in drought susceptible areas of northwestern India. However, ICRISAT scientists recognized that the early maturing hybrid would be susceptible to downy mildew and began developing an improved version in 2000. Using innovative methods of marker assisted backcrossing "HHB 67-Improved" was released in 2005 after a relatively short R&D lag and gave farmers in northwestern India access to a hybrid that is both early maturing and downy mildew resistant. "HHB 67-Improved" was the first marker-assisted field crop hybrid cultivar in the public domain to reach farmers' fields in India.

Data for the analysis of HHB 67-Improved come from Harinarayana (2012) and from data compiled and provided by ICRISAT directly. Cost information from these two sources is somewhat divergent. The data used here are taken from spreadsheets provided by ICRISAT. Use of the higher cost values from Harinarayana does not appreciably affect results. Data from ICRISAT and Harinarayana provide for direct comparison of yields and costs for adopters and non-adopters as well as direct measurement of the adoption level by year. To mitigate the effect of unobserved differences between adopters and non-adopters, the yield effect used here is the differential over the last four years of the eight year period for which data are available. The first four years of data are excluded on the grounds that the earliest adopters are likely to be exceptional farmers whose outcomes cannot be directly compared to non-adopters. After four years, the variety had become sufficiently widespread that the unobserved differences between adopters and non-adopters are likely to be less significant. Market prices reported for pearl millet are highly variable. Based on the tendency for pearl millet to be a substitute for wheat in consumption, the price of internationally traded Indian wheat is used as the base for the pearl millet price in this study. Given an upward trend in wheat and pearl millet prices, a 1% annual growth rate in price is applied to the base year price.

3.5 Improved Pigeonpea in Northern Tanzania

ICRISAT's improved pigeonpea for Eastern and Southern Africa has given farmers in that region a new export crop with a strong market in South Asia. The data for the analysis of improved pigeonpea comes from a study of the crop in Northern Tanzania (Dalton and Regier 2013). Focusing only on one area in which the pigeonpea program has been active, this study captures only a part of the program's impact. Dalton and Regier provide district level adoption rates, yield effects and cost impacts based on a multivariate econometric analysis of household survey data that attempts to correct for selection bias. This analysis uses the weighted average technical parameters to make a single regional estimate and treated the region as an open economy in the larger market. Aggregate results of the impact analysis in Dalton and Regier (2013), which applied the DREAM model, and those generated in this application of the DREAM model are very similar despite the simplification of the market structure applied in this estimation. Cost data provided in Dalton and Regier (2013) are used to estimate investment costs and are assumed to have been reported in constant 2010 US dollars. Based on observed prices over the period, a 0.5% growth trend is applied to a base price of $198/ton. Following Dalton and Regier this simulation projected sustained use of the technology to the year 2022. Extending beyond 2013 represents a deviation from the practice used for other cases assessed in this report.

3.6 Fusarium Wilt Resistant Pigeonpea in India

The analysis of wilt resistant pigeonpea variety (Maruti) in Karnataka, Maharashtra, Andhra Pradesh and Madhya Pradesh, India, represents an extension of Bantilan and Joshi (1996), using more current data provided by ICRISAT to lengthen the period of ex post analysis up to 2013. Data provided in Bantilan and Joshi (1996) have been transformed to convert values to constant 2010 US dollars. Recent data provided by ICRISAT indicates that the yield differential attributable to adoption has grown since 1995. Thus the yield impact used in the baseline analysis here is higher than that applied in Bantilan and Joshi (1996). The value from Bantilan and Joshi (1996) is well over the lower bound used in the pessimistic scenario. It is not clear what steps were taken to avoid selection bias that could lead to overestimated yield effects. However, given the adoption rate of over 60%, unobserved factors are not likely to drive the yield differential. Nonetheless, since there are no controls for observable differences between areas under improved varieties and others, it is possible that the high observed yield difference could be attributed in part to environmental factors other than seed variety. Recent observations suggest that there has been disadoption of the Maruti variety in recent years. Thus, this analysis models 10 years at the maximum adoption level reported by Bantilan and Joshi (1996), followed by gradual disadoption. Prices for pigeonpea have shown an upward trend since 1975, which is captured with a 1% annual growth trend from the base price.

3.7 Fertilizer Microdosing in Zimbabwe

Fertilizer use through microdosing has led to the reintroduction of fertilizer for cereals production in semi-arid areas of southern and western Africa. By making fertilizer use more accessible and effective, microdosing has dramatically increased yields for maize and pearl millet. Data for the analysis of fertilizer microdosing in Zimbabwe are from Winter-Nelson et al. (2013) and refer to application of microdosing to maize. Winter-Nelson et al. (2013) used a multivariate econometric analysis to estimate adoption rates and productivity effects based on a sample of households that had received training in the technology compared to a sample that had been unexposed to the technology. That study provided a set of lower bound and upper bound parameters, as well as most likely estimates used here. The pessimistic scenario presented here uses parameters for productivity effects and elasticity that are lower than the lower bounds in Winter-Nelson et al. (2013). Cost data were presented in constant 2010 US dollars.

3.8 Fertilizer Microdosing in Niger

In Niger fertilizer microdosing has been applied to pearl millet with impressive results. The costs attributable to fertilizer microdosing in Niger were estimated based on those reported for Zimbabwe. Production data and productivity effects were provided by ICRISAT scientists based on a range of observations in field stations and on farm plots. Other data for this case were provided by the ICRISAT-Niamey office.

3.9 HPRC Pearl Millet Hybrids in India

The Hybrid Parents Research Consortium (HPRC) represents a novel partnership involving ICRISAT and private sector seed companies as well as the Indian national agricultural research system. Through the release of new hybrids using parental lines from the HPRC, yield increases of about 2% per year have been achieved each year since the releases began. In contrast to other technologies considered here, which generally provide a large one time increase in productivity, the HPRC results in repeated releases of improved varieties which generate annual productivity improvements that compound over time. While HPRC-bred hybrids seed represents about 54% of pearl millet planted, ICRISAT parental lines are used as one of the parents in the hybrids, the other line being their proprietary line in the hybrids released. Reflecting the nature of HPRC, this analysis attributes to ICRISAT 0.75% annual increases in yield, rather than the full 2%, and estimates that 25.5% of planted hybrids are from ICRISAT-sourced parental lines. Costs incurred by ICRISAT in the HPRC Pearl Millet program were reported by ICRISAT-Patancheru scientists.

3.10 HPRC Sorghum Hybrids in India

The HPRC partnership has facilitated development and release of hybrid sorghum, similar to pearl millet. Since sorghum area and production have been on a downward trend in India despite yield improvements, a -0.25% growth trend was imposed on the model for sorghum hybrids. A -0.75% annual rate of change is applied to the base price to reflect the trend in sorghum prices over the period of study. Costs of the sorghum hybrid investments were provided by ICRISAT-Patancheru scientists. The initial year in which research investments began was unclear from the source material. In all HPRC activities there is a short lag between release and adoption because the partnership with the private sector ensures rapid diffusion of varieties. Moreover, the structure of the HPRC implies release of new varieties on a regular basis, implying continuous increases in yield for HPRC sorghum and pearl millet.

3.11 Integrated Watershed Management in Lucheba, China

The integrated watershed management program represents a natural resource management strategy that both increases the value of output by enabling farmers to adopt production of high value crops, while enhancing the sustainability of water management. This model was started in India and scaled out in China, Thailand and Vietnam. Data for the impact analysis of watershed management in Lucheba, China, are from Marothia (2013). The watershed management project in Lucheba has brought positive changes in the village economy in terms of tangible and intangible benefits. Tangible impact indicators in terms of farm based employment and income show an enhanced labor absorption by 43.5% and labor income by 81.8% through diversification in favor of high value vegetable crops. Farm income from crops, largely vegetables, has increased by 192.3%, whereas income from livestock and non-farm has reduced by 100% and 63.3%, respectively, in the post watershed program. In general total income at household level has increased by 32%. This analysis represents only a small share of the investments and returns to integrated watershed management initiatives.

3.12 Sweet Sorghum, Pigeonpea Genome, Guinea-Race Sorghum

Three of the ICRISAT Jewels, sweet sorghum, pigeonpea genome, and Guinea-race sorghum show great promise, but have impacts that are yet to be observed. Results of ex ante impact assessments are provided for these initiatives. The estimates provided are based on ICRISAT scientists' "best guesses" of parameters for actual productivity effects and adoption. These estimates should be taken as indicative. Because the uncertainty around these parameters is itself unbounded, only baseline results are presented. The basis for determining what constitutes a lower bound for impact is not available. Because of the high degree of uncertainty surrounding the data for these initiatives, they are not included in calculating the average return across projects.

04 Results

The ROI values range from

$9 to over $100 per dollar invested ■

The economic surplus analysis yields estimates of internal rates of return (IRR) ranging from 16% to 96%. Estimated economic impacts are presented in Table 3. The return on investment (ROI) values range from $9 to over $100 per dollar invested. Higher returns on investment are observed for technologies that have either had long periods under adoption, such as Wilt Resistant Pigeonpea and Drought Tolerant Groundnuts (Malawi), or have been adopted over larger scales. Differences in observed rates of return are also attributable to differences in the R&D and adoption lags across initiatives. HHB 67-Improved, HPRC pearl millet and HPRC sorghum all have relatively short R&D or adoption lags, and as a result, have yielded relatively high returns on investment. Because of the short adoption lag that HPRC facilitates, the two HPRC case studies evaluated here have extremely high rates of return despite productivity effects that are typical or low for this set of technologies. Due to its scale of application and its long period of use, Wilt Resistant Pigeonpea has generated a NPV that dwarfs the other initiatives analyzed here.

The present value figures for the various projects shown in Table 3 are not directly comparable, as each is defined to the initial year of the specific project. These values can be inflated to a common base year and summed to calculate total costs and returns and an average ROI. Table 4 shows the present value figures for costs and benefits in the initial year of each program and those values inflated to 2010, using a 5% interest rate. Based on the values of costs and benefits in the last two columns of Table 4 below, Table 3 shows that, excluding the Wilt Resistant Pigeonpea variety, also known as Maruti, the average ROI across the projects for which ex post analysis was completed is $43.02 per dollar invested. The corresponding IRR is 41.46%. Each of these values is a weighted average with weights based on the share of total benefits attributed to each project. Wilt Resistant Pigeonpea was adopted by farmers in a large scale and it remained in the field for a long period relative to all other ICRISAT Jewels. Therefore, if we count the impacts of the Wilt Resistant Pigeonpea, the average returns become significantly high.

Table 3. Rates of Return to ICRISAT Jewels.

Selected Jewels of ICRISAT	Present Value of Cost (in 2010 US$)	Present Value of Benefits (in 2010 US$)	Benefit per $ invested (ROI)	Internal Rate of Return (IRR)
Drought Tolerant Groundnut in Malawi	$346,810	$35,320,730	$101.59	40.27
Drought Tolerant Groundnut in Nigeria	$1,561,310	$77,557,740	$49.67	41.77
Drought Tolerant Groundnut in Anantapur	$971,530	$55,552,710	$57.18	22.65
Watershed Management in Lucheba	$ 472,191	$14,707,180	$31.15	20.04
Extra-Early Pearl Millet Hybrid in Northwestern India	$3,636,430	$158,411,270	$43.56	19.51
Pigeonpea in Northern Tanzania	$700,860	$6,135,690	$8.75	16.71
Fusarium Wilt Resistant Pigeonpea in India	$4,438,050	$470,563,230	$106.03	32.06
Fertilizer Microdosing in Zimbabwe	$2,674,970	$29,705,220	$11.10	35.58
Fertilizer Microdosing in Niger	$3,000,000	$123,045,320	$41.02	38.37
HPRC Pearl Millet in India	$2,062,550	$126,301,160	$61.23	70.28
HPRC Sorghum in India	$1,559,040	$74,829,160	$48.00	65.43
Guinea-Race Sorghum Hybrids in Mali (ex ante)	$1,020,470	$80,560,140	$78.94	35.63
Sweet Sorghum in India (ex ante)	$1,950,000	$56,251,530	$28.85	33.52
Pigeonpea Genome in India (ex ante)	$1,352,280	$120,043,850	$88.77	34.96
AVERAGE (ex post only)			$70.36	35.31
AVERAGE (ex post only, excluding Wilt Res. Pigeonpea)			$43.02	41.46

Note: Values are in constant (2010) US dollars. NPV figures are not comparable across rows due to differences in base years. Average value of ROI is estimated by compounding the value of all costs and benefits to 2010 from the base year of each initiative and taking the ratio of benefits to costs. The average IRR is calculated as the weighted average of the individual IRR values, with weights based on the share of total benefits.

Table 4. Present Value In Common Base Year (2010).					
Case	Base Year	Present Value of Cost in Base Year	Present Value of Benefits in Base Year	Present Value of Cost Inflated to 2010	Present Value of Benefits Inflated to 2010
Groundnut in Anantapur, India	1991	$971,530	$55,552,710	$2,455,007	$140,378,931
Groundnut in Malawi	1983	$346,810	$35,230,730	$1,294,800	$13,153,291
Groundnut in Nigeria	1996	$1,561,310	$77,557,740	$3,091,287	$153,559,020
Watershed in Lucheba, China	2003	$472,191	$14,707,180	$664,420	$20,694,479
Pearl Millet Hybrid in India	1999	$3,636,430	$158,411,270	$6,219,529	$270,937,630
Pigeonpea in Tanzania	1993	$700,860	$6,135,690	$1,606,384	$14,063,113
Wilt Resistant Pigeonpea in India	1975	$4,438,050	$470,563,230	$24,480,352	$2,595,634,008
Microdosing Zimbabwe	2001	$2,674,970	$29,705,220	$4,149,756	$46,082,545
Microdosing Niger	1994	$3,000,000	$123,045,320	$6,548,623	$268,592,502
HPRC Pearl Millet	2000	$2,062,550	$126,301,160	$3,359,676	$239,933,295
HPRC Sorghum	2000	$1,559,040	$74,829,160	$2,539,511	$143,340,137

Note: Base year values inflated to 2010 at 5%. All values in 2010 US dollars.

Given uncertainty in the measurement of various parameters, pessimistic estimates of the return are estimated by setting the elasticity of supply and the productivity effect (k-shift) at half of their baseline values reported in Tables 1 and 2. This adjustment aligned with exclusion of impacts of the Wilt Resistant Pigeonpea leads to parameter values that are lower than any lower bound estimate cited by the sources used. Nevertheless, as the figures in Table 5 depict, even under highly conservative estimates of parameters, the “jewels” have each performed well. The pessimistic parameter values lead to ROI values ranging from $3.85 to $49.85 per dollar invested and an average ROI of $21.97 per dollar invested. The overall IRR under this pessimistic scenario is 42.26% and ranges from 12.15% to 73.48% across the studies. In a highly pessimistic scenario the baseline adoption rate is set at 50% of the baseline value as well as the productivity effect and the supply elasticity. Even under this extremely unlikely scenario, the ROI is substantial for all projects (excluding Wilt Resistant Pigeonpea) and averages $11.08 across the studies. The overall IRR under highly pessimistic scenario is 32.49% and ranges from 8.42% to 55.08% across studies. (ROI and IRR values for the baseline, pessimistic and highly pessimistic scenarios are presented in Figures 1 and 2 and in Table 4.)

Figure 1. Estimated Internal Rates of Return (IRR).

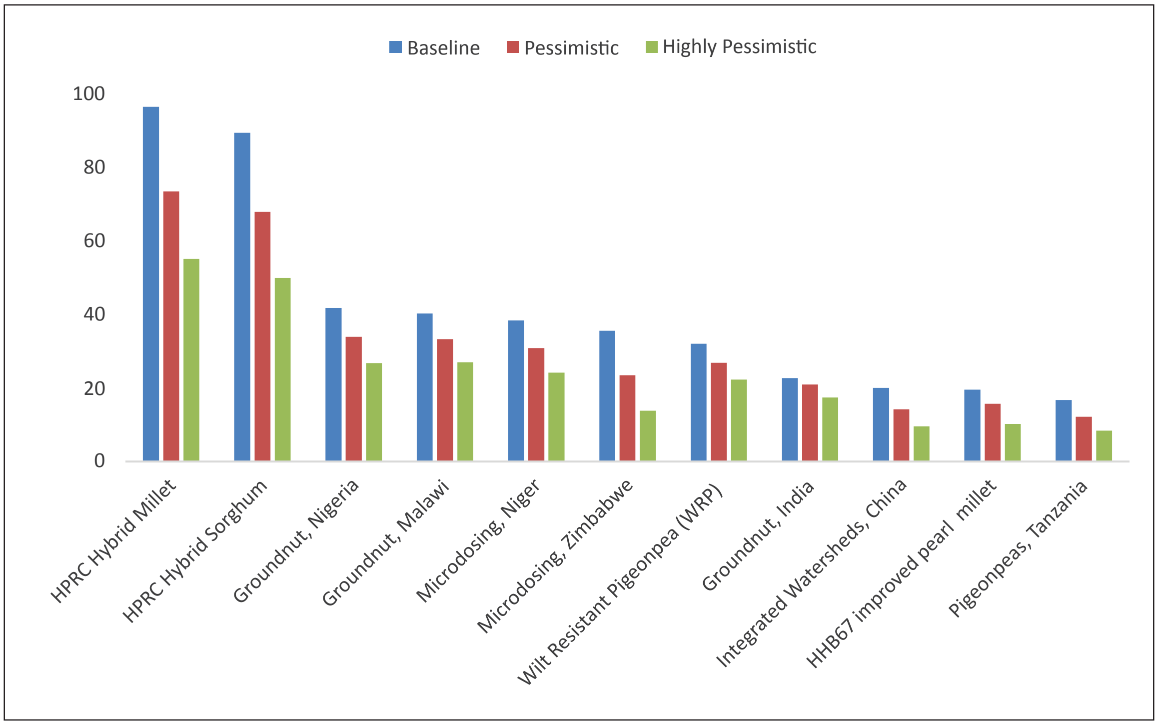

Figure 2. Estimated Returns on Investment (ROI).

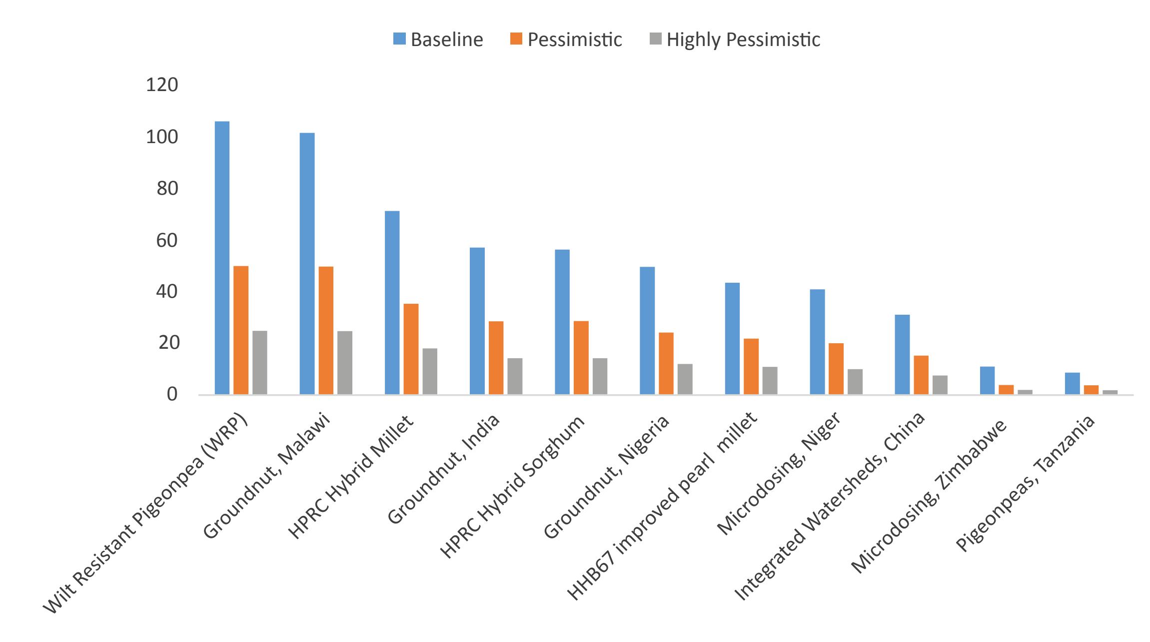

Table 5. Rates of Return under Pessimistic and Highly Pessimistic Parameter Values.

Selected Jewels of ICRISAT	Present Value of Benefits, Pessimistic	Present Value of Benefits, Highly Pessimistic	ROI, Pessimistic	ROI, Highly Pessimistic	IRR, Pessimistic	IRR, Highly Pessimistic
Fertilizer Microdosing in Zimbabwe	$10,666,273	$5,322,244	3.99	1.99	23.44	13.81
Fertilizer Microdosing in Niger	$60,281,150	$30,108,640	20.09	10.04	30.85	24.15
Drought Tolerant Groundnut in Malawi	$17,287,190	$8,616,240	49.85	24.84	33.27	27.04
Drought Tolerant Groundnut in Nigeria	$37,855,860	$18,852,480	24.25	12.07	33.89	26.79
Drought Tolerant Groundnut in Anantapur, India	$27,810,480	$13,874,130	28.63	14.28	20.98	17.45
Watershed Management in Lucheba, China	$7,238,100	$3,577,560	15.33	7.58	14.83	10.27
Extra Early Pearl Millet Hybrid in Northwest India	$79,534,220	$39,706,070	21.87	10.92	37.80	29.52
Pigeonpea in Northern Tanzania	$2,695,480	$1,328,570	3.85	1.90	12.15	8.42
Fusarium Wilt Resistant Pigeonpea in India	$222,262,780	$110,773,710	50.08	24.96	26.82	22.26
HPRC Pearl Millet in India	$73,139,540	$37,266,130	35.46	18.07	73.48	55.08
HPRC Sorghum in India	$22,359,290	$44,758,860	28.71	14.34	67.92	49.96
AVERAGE			34.17	17.10	32.44	25.99
AVERAGE (excluding Wilt Res. Pigeonpea)			21.97	11.08	42.26	32.493

Note: Average value of ROI is estimated by compounding the value of all costs and benefits to 2010 from the base year of each initiative and taking the ratio of benefits to costs. The average IRR is calculated as the weighted average of the individual IRR values, with weights based on the share of total benefits.

05 Conclusion

The high returns to investment indicate

that these projects have been strikingly effective in raising farm productivity for smallholders in fragile environments ■

This analysis of the return on investments in ICRISAT's Jewels confirms that from an economic surplus perspective the projects yielded exceptionally high returns. These results should be treated with some care. In the first instance, the projects analyzed here were not chosen as typical R&D efforts. Rather they represent programs that were identified as showpieces of the ICRISAT successes. Second, the data on which these estimates of return on investment are based was limited. In some cases the data on investment cost reflect arbitrary decisions concerning the point at which research costs could be attributed to a specific program and in other cases rough estimates of what costs were likely to have been were applied. The adoption of full cost recovery accounting systems in ICRISAT is likely to facilitate more precise estimation of program costs and of rates of return in the future. Finally, the measurement of the farm-level yield and cost impacts of the new technologies was not consistent across the studies that served as sources of data for this analysis. In some cases the K-shifts are therefore likely to have been poorly estimated. New standards for impact measurement and the use of ICRISAT's panel data set may lead to more accurate measures of impact in the future.

Despite the shortcoming of existing data, baseline results without including impacts of the Wilt Resistant Pigeonpea show a return on investment of $43.02 per dollar invested. With the inclusion of the impacts of the Wilt Resistant Pigeonpea, the baseline return on investment reaches $70 per dollar invested. Even under the pessimistic scenario, ICRISAT's Jewels appear to have yielded impressive returns. The high returns to investment indicate that these projects have been strikingly effective in raising farm productivity for smallholders in fragile environments. The results for the ICRISAT Jewels are also consistent with other assessments of return on investment in agricultural research and development, with highly impressive payoffs to the society.

References

Alston JM, Norton GW and **Pardey PG.** 1998. Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. New York: CAB International.

Alston JM, Chang-Kang C, Marra MC, Pardey PG and **Wyatt T.** 2000. A Meta-Analysis of Rates of Return to Agricultural Research and Development: Ex Pede Herculem? Washington DC: International Food Policy Research Institute.

Bantilan MCS and **Joshi PK.** 1996. Returns to Research and Diffusion Investments in Wilt Resistance in Pigeonpea. Impact Series No. 1. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Bervejillo J, Alston JM and **Tumbler J.** 2011. Economic Returns to Public Agricultural Research in Uruguay. RMI-VWE Working Paper #1103, Davis, CA, USA.

Birthal PS, Nigam SN, Narayanan AV and **Kareem KA.** 2011. An Economic Assessment of the Potential Benefits of Breeding for Drought Tolerance in Crops: A Case of Groundnut in India. Research Bulletin No. 25. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India.

Dalton T and **Regier G.** 2013. "Assessment of the Impact of Improved Pigeonpea Development by ICRISAT in Northern Tanzania". Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Harinarayana G. 2012. Impact Assessment of Pearl Millet Hybrids HHB67 and HHB 67 Improved on Production in North-West India. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

ICRISAT. 2012. The Jewels of ICRISAT. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Lindner R, McLeod P and **Mullen J.** 2013. Returns to ACIAR's Investment in Bilateral Agricultural Research. ACIAR Impact Assessment Series No. 86. Canberra: Australia Centre for International Agricultural Research.

Lubulwa G and **McMeniman S.** 1999. ACIAR Economic Impact Model for Use in Project Development (Ex-Ante) and Completed Project (Ex-Post) Evaluations: A Users Manual. Contributed paper to the 43rd Annual Conference, Australian Agricultural Resource Economics Society, 20-22 January 1999. Christchurch, New Zealand.

Marothia DK. 2013. Impact Assessment of Lucheba Watershed, China. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics,.

Ndjeunga J, Ntare BR, Ajeigbe H, Echekwu CA, Ibro A and **Amadou A.** 2012. Adoption Impacts of Modern Groundnut Varieties in Nigeria. BP 12404, Niamey, Niger (Via Paris): ICRISAT-Niamey.

Simtowe Franklin and **Mausch Kai.** 2012. Assessing the Effectiveness of Agricultural R&D in Eastern and Southern Africa: Cases of Groundnuts, Pigeonpea, and Sorghum Crop Improvement Programs. ICRISAT's Objective 1 Report for the DIVA Project. April 2012.

Winter-Nelson A, Stack J, Mvumi B and **Pedzisa T.** 2013. Impact of Microdosing Research and Development in Semi-Arid Zimbabwe.

Wood S, You L and **Baitx W.** 2001. Dynamic Research Evaluation for Management: DREAM Version 3. Washington, DC: International Food Policy Research Institute.

Zereyesus YA and **Dalton TJ.** 2013. Rates of Returns to Sorghum and Millet Agricultural Research and Development.Manhattan, KS: Kansas State University.

Appendix A

ICRISAT Partners

Accion Fraterna, Anantapur District, Andhra Pradesh, India

Acharya NG Ranga Agriculture University (ANGRAU), Hyderabad, India

Adriana Seed Company, Londrina, PR Londrina, Brazil

Advanced Research Institutes (ARIs) in participating countries

Agricultural Research Station (ARS), Gulbarga

Advanta India Limited

Ajeet Seeds Limited

Alliance for a Green Revolution in Africa (AGRA)

Andhra Pradesh State Seeds Development Corporation Ltd (APSSDC)

Ankur Seeds Private Limited

Atash Seeds Pvt Ltd

Bayer BioScience Pvt Ltd

BAIF Development Research Foundation (formerly Bharatiya Agro Industries Foundation)

Beijing Genome Institute (BGI), Shenzhen, China

Beijing Genome Institute (BGI), USA

Bhopal Yuva Paryavaran & Sikshan Sansthan (BYPASS)

Biogene Agritech, Ahmedabad, Gujarat

Bioseeds Research India Pvt Ltd, Hyderabad, Andhra Pradesh

Chinese Academy of Agricultural Sciences (CAAS)

Cold Spring Harbor Laboratory, New York

Cooperative for American Relief Everywhere (CARE)

Conseil Ouest Africain pour la Recherche et le Développement Agricole/West and Central African

DeVGen Seeds and Crop Technology Pvt Ltd

Dhanlaxmi Crop Science Private Limited

Council for Agricultural Research and Development (CORAF/WECARD)

Central Research Institute for Dryland Agriculture (CRIDA), India

CGIAR Consortium

CGIAR Generation Challenge Programme (GCP)

Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar, Haryana, India

Department of Agriculture, Andhra Pradesh, India

Department of Agriculture, India

Department of Agriculture, Thailand

Department of Agricultural Research, Myanmar

Department of Land Development (DoLD), Thailand

Dr Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola

Embrapa - Brazilian Agricultural Research Cooperation (Empresa Brasileira de Pesquisa Agropecuária)

Food and Agriculture Organization of the United Nations (FAO)

Global Crops Diversity Trust, Rome

Ganga Kaveri Seeds Pvt Limited

Godrej Seeds and Genetics Ltd

Hytech Seed India Private Limited

The Malian Institut d'Economie Rurale (IER)

Indian Council of Agricultural Research (ICAR)

Indian Institute of Pulses Research (IIPR), India

International Centre for Agricultural Research in the Dry Areas (ICARDA)

International Cooperation Centre for Agronomic Research for Development (CIRAD), France

International Fund for Agricultural Development (IFAD)

Institute for Agricultural Research, Nigeria

Institute of Grassland and Environmental Research, Aberystwyth

Institut National de l'Environment et des Recherches Agricoles (INERA), Burkina Faso

Institut Sénégalais de Recherches Agricoles, Senegal Irish Aid

John Innes Centre, Norwich

JK Agri Genetics Limited

Kanchan Ganga Seed Co Pvt Ltd

Karnataka State Seeds Corporation Limited

Kaveri Seed Company Pvt Ltd

Kesar Enterprises Limited

Krishidhan Seeds Private Limited

Maharashtra Krishi Vidyapeeth (MKV), Parbhani

Maharashtra State Seeds Corporation (MSSC)

Metahelix Life Sciences Pvt Ltd

Millennium Villages Project

Monsanto Company

Myanmar Agriculture Service (MAS)

Namdhari Seeds Private Limited

Nath Biogene (I) Limited

Navbharat Seeds Private Limited

National Agricultural Research Systems (NARS) of participating countries

National Bureau of Plant Genetic Resources (NBPGR), India

National Center for Genome Resources, Santa Fe, New Mexico, USA

National Food Security Mission, India

National Seeds Corporation (NSC), India

National Smallholder Farmer Association of Malawi (NASFAM)

National University of Ireland, Galway

Nimbkar Seeds Pvt Ltd, Phaltan, Maharashtra

Nirmal Seeds Private Limited

Nu Genes Private Limited

Nuziveedu Seeds Pvt Limited

Pioneer Overseas Corporation

Sagar Laxmi Seeds

Salien Agricultural Research Institute (SARI), Tanzania

Shakthi Vardhak Hybrid Seeds Private Limited

SM Sehgal Foundation, Hyderabad

Spriha BioSciences Pvt Limited

State Agricultural Universities (SAUs), India

State Farms Corporation of India Ltd (SFCI)

TriMurti Plant Sciences Pvt Ltd

University of California, Davis

University of Copenhagen

University of Georgia

University of North Carolina

University of Wales, Bangor, UK

United States Agency for International Development (USAID)

Vibha Agrotech Ltd, Madhapur, Hyderabad

Vietnam Academy of Agricultural Sciences (VAAS)

"This report offers a very well executed analysis of the economic return on investment from 11 crop research programs undertaken by ICRISAT in recent years, with some projections of future benefits in ex ante analyses of 3 other programs. Data and methods are presented clearly, and results are consistent with those found by other researchers addressing a wide variety of other crop research programs around the world. This portfolio of ICRISAT programs is estimated to have generated a rate of return of 26-35% under scenarios ranging from "highly pessimistic" to "conservative".

In my view the report is clear and complete as it stands.
ICRISAT is justifiably proud of these jewels, and is to be commended for continuing to document their impacts."

WILLIAM A. MASTERS

Professor, Friedman School of Nutrition Science and Policy and Department of Economics (by courtesy), Tufts University

"This is a heroic attempt to try to put some aggregate impact results (economic rates of return in this case) together based on some of ICRISAT's major research success stories, i.e., its Jewels. The process used in the aggregation across the studies is explained well, as is the generic description of standard economic surplus methods used here and in some of the individual base studies. Sensitivity analyses were also done, which is good given the unknown precision on the estimates in most of these individual case studies.

I would recommend, assuming this has priority to ICRISAT, conducting a more in-depth treatment of the estimated impact of these individual case studies. **Even if some are rejected for lack of information or clarity or inappropriate methods, no doubt a handful will emerge as being credible and a basis for doing the aggregate analysis.**"

TIMOTHY KELLY

Secretary, Standing Panel on Impact Assessment, Independent Science and Partnership Council, CGIAR

About ICRISAT

The **International Crops Research Institute for the Semi-Arid Tropics** (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, of whom 644 million are the poorest of the poor. ICRISAT innovations help the dryland poor move from poverty to prosperity by harnessing markets while managing risks – a strategy called Inclusive Market-Oriented Development (IMOD).

ICRISAT is headquartered in Patancheru, Telangana, India, with two regional hubs and five country offices in sub-Saharan Africa. It is a member of the CGIAR Consortium. CGIAR is a global research partnership for a food secure future.

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