Impact Assessment of ICRISAT Village Level Studies: 1975 to 2013

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Impact Assessment of ICRISAT Village Level Studies: 1975 to 2013

An independent external review commissioned by ICRISAT

John Denis Mullen

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INSTITUTE FOR THE SEMI-ARID TROPICS

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Executive Summary

The village level studies (VLS) program was identified as one of ICRISAT's 16 jewels in 2012 (40th anniversary). The program began in 1975 with 240 households in two villages in each of the three regions in the semi-arid tropics (SAT) of India. In 1980, four more villages were added, resulting in a total of 400 households. A repeat survey was carried out in these villages in 1989. Another 10 villages (250 households) in Burkina Faso and Niger were studied in the 1980s and in late 2000s. During 2001–2008, the household survey was carried out in six villages in India. In 2009, the VLS Project was rejuvenated, renamed as the VDSA (Village Dynamics in South Asia) project, and expanded to cover 1824 households in 42 villages in six states of SAT in India, three states in east India and 11 districts in Bangladesh. Other partners in the project included the International Rice Research Institute (IRRI), Indian Council of Agricultural Research (ICAR) institutes (National Centre for Agricultural Economics and Policy Research—NCAP, New Delhi; ICAR Research Complex for Eastern Region, Patna; Directorate of Water Management--DWM, Bhubaneswar) of India, and other research organizations and state agricultural universities in India and Bangladesh. From 2009 onwards, the funding for the expanded project came from the Bill & Melinda Gates Foundation.

There have been many paths by which the resources used in the VLS and VDSA projects complemented with resources from partners have achieved the goal of enhancing the welfare of rural households and the village economies in South Asia - by 'raising the voices of the poor' in the words of the goal of the VDSA project. Many benefits, 'spillovers', have also flowed to users around the world.

The objectives of this impact assessment include:

- To identify the direct outputs of the projects and the set of intermediate outcomes derived from the direct outputs by scholars around the world and the VLS/VDSA team;
- To identify and describe the paths by which these intermediate outcomes have resulted in changes in economic and social welfare and increases in scientific knowledge and capacity;
- To assess the likelihood that some of the intermediate outcomes have made significant contributions toward economic and social welfare and to scientific knowledge and capacity;
- To estimate the investment by ICRISAT and partners in the VLS/VDSA projects;
- To estimate the economic gains from the VLS contribution to bringing forward the adoption of Maruti pigeonpea in Akola and neighboring districts in Maharashtra; and
- To conduct a tracer study of the learner participants in the VLS/VDSA projects so as to assess not only the capacity built from their time in the projects but also how they used this capacity subsequently.

Many pathways to impact

There are a small set of direct outputs from the data collection dimension of these projects and then, with the input of further resources from cooperating individuals or institutions across the world that use these data, there are a wide range of intermediate outcomes. These outcomes in the hands of final users are reflected in gains in scientific capacity, and in economic and social gains. This flow of inputs, direct outputs, intermediate outcomes, and final impacts is represented schematically in Figure 1 (explained in section 2).

Household panel datasets

The household panel dataset of many economic and social variables is the key output from the VLS/ VDSA projects that have been used by economists at ICRISAT and around the world. The original VLS database was unique and allowed a much improved understanding about how SAT households make choices about production, consumption, investment and savings in a very uncertain world. This can only be done in an econometrically sound way by following many households over a period of

several consecutive years. There are competitors with the VDSA databases but they are imperfect competitors when a panel dataset over many years and households is required. The household dataset was complemented by data assembled at a meso or district level. The datasets allowed the welfare of poor rural households to be tracked over time and were comprehensive enough to allow gender and nutrition issues to be traced as well. From December 2011 to January 2015, 792 unique users from 39 countries downloaded the newly released data. This included 366 students of which 212 were PhD students from about 150 universities/ institutes around the world. Most researchers and students identified production economics as the research area where they planned to apply the data (section 6.2).

These datasets have the characteristics of global public goods (section 1.2). Because the findings from research using this data have application across the world, not just in SAT India, there would likely be underinvestment in assembling this data were it left to Indian institutions. It has to be funded globally and this has been the case.

Infrastructure built by the projects

The second direct output of the VLS/VDSA projects is an environment and infrastructure within the villages that is conducive to applied experiments or simulations by bio-physical scientists, economists and sociologists. A unique feature of the project is locating resident investigators in the villages for collecting the data, roughly on a monthly basis. Their presence also facilitated the trialing of technologies on village farms and their evaluation in a whole farm (household) context over years when the climate and prices varied. Many technologies and policy changes have failed because the incentives facing farm households have not been adequately considered.

The VLS/VDSA also facilitated special purpose surveys and provided an infrastructure and baseline data for larger studies. This baseline data enriched the analysis of survey data and helped control for observed effects in the year of a survey which may be 'seasonal' in some dimension. A current special purpose survey investigating nutrition, gender and their relationship with agriculture makes use of the VLS/VDSA infrastructure and is enriched by the baseline data on gender and nutrition extending back to the start of the VLS project.

Intermediate outcomes

Users, both at ICRISAT but also around the world, have applied additional resources to these two direct outputs, generating many intermediate outcomes that have been classified into five groups:

- Capacity building through training
- Additions to scientific knowledge (new methods and theories)
- Accelerated technology development
- Research priority setting
- Accelerated rural policy development

There are some unique features of the VLS/VDSA projects that make it unlikely for many of the outcomes to have been achieved in any other way. These features include:

- The two groups of panel data over 10 years and 10–15 years, complemented by meso data, allowed the impact of uncertain weather and market conditions to be accounted for when studying farm household decision making under risk;
- The resident investigator who collected data at monthly intervals and subsequent quality control processes contributed to the accuracy of the database. A level of trust built up between households and resident investigators as the projects progressed also contributed to the accuracy of sensitive household information;
- The comprehensiveness of the recorded farm and household transactions allowed many research questions to be addressed from a whole farm/household perspective.

Methodology of the report

The best outcome from this impact assessment process would have been a quantitative estimate of the economic benefits attributable to the VLS/VDSA projects which could have been compared to the investment in the project by ICRSISAT and the many who have used the databases – or at least the empirical assessment of enough outcomes such that the benefits of this sample exceeded the total investment in the VLS/VDSA projects.

However, tracing and describing these many impact pathways have been challenging tasks. In fact, it has been beyond the resources here to exhaustively identify and describe all these pathways. In following sections, examples from each of the intermediate outcomes, which are expected to have had significant final impacts, have been described but many remain unidentified. It certainly has not been my purpose to document all the activities of the VLS/VDSA projects. Rather I have tried to identify a selection of activities where the use of the VLS/VDSA databases and infrastructure have been important factors in generating outcomes that are likely to have been influential to households, science managers and policy makers and to have added to the stock of scientific capacity and knowledge. Because my expertise does not extend across all these areas my judgments have sometimes been subjective.

In addition, the flow of benefits from capacity building and additions to scientific knowledge are not easily quantified using the economic surplus techniques traditionally applied to estimating the impact of new agricultural technologies and rural policy shifts.

The goal has been evidence based, replicable assessments (even if unquantified) of the many impacts of the VLS/VDSA projects by identifying plausible but probabilistic causal links between inputs and outputs along the impact pathway. Why farmers adopt particular technologies, why science managers choose particular projects, why policy makers adopt particular polices are all difficult to discern. Hence, while care has been taken in attributing influence to the VLS/VDSA projects, all of these statements are probabilistic or subjective. I have attempted to make a judgment about whether the use of VLS/VDSA data has led to findings likely to have been influential. My judgements about whether activities have been influential are based on four factors[1] (although often this process of consideration has been incomplete):

- Whether they have used the unique time series and cross section characteristics of the data to analyze choices by rural households when weather and prices are uncertain;
- Whether they have used the village infrastructure allowing technologies to be trialed, special surveys to be conducted and sensitive data to be collected accurately;
- Whether the village household perspective they provided was not otherwise available (although I was unable to assess this in many instances);
- Whether they have exploited these three factors to test hypotheses that challenged the conventional wisdom about the consumption and production choices of rural households and the behavior of markets in which they operate, whether they provided new information in other words.

Despite the inability to empirically estimate many VLS/VDSA impacts, impact pathways have been described in ways consistent with supply and demand shifts in the traditional economic surplus framework. A critical component of benefit cost analysis is identifying a plausible 'without research' scenario. Often a plausible without research scenario for the VLS/VDSA projects is that adoption of technology, change in research priorities or policy settings or additions to the stock of knowledge would have been delayed by several years. The economic framework is explained in sections 3 and 4 (Figures 2 and 3).

1. Perhaps there is a degree of ex post rationalisation here.

Highlights from the five intermediate outcomes

Brief summaries follow of prominent activities within each of the five intermediate outcomes that are likely to have an impact on the welfare of rural households, even if indirectly. Detailed discussion of these five areas can be found in Sections 8 – 12.

Capacity building through training

All VLS/VDSA activities have a capacity building dimension, some through formal training and some through informal 'learning by doing' in the course of project activities. Much of this capacity has been built in those who use the data, far removed physically from ICRISAT. Capacity built has value if it is eventually applied in the development of new technologies or farm policies that enhance the welfare of rural households. Recently, Davis et al. (forthcoming 2015, section 8.1)), focusing on formal training at ICRISAT, conducted a tracer study of the 211 'learner participants' (LPs) who have done training with the VLS/VDSA team since the start of the projects. They gave strong emphasis not only to describing the capacity built during training but also to identifying how that capacity has been used in the participants' later careers. About three-fourths of the respondents said that their training was relevant to themselves and their institutions, and another three-fourths agreed that they had an increased capacity for research. They found that many of those trained respondents now work in positions where they are likely to be influential, giving credence to the subjective statements about the contribution of the VLS training. In addition, they found that 16 of the respondents had written 24 articles using the VLS related resources, some of them published in high-impact journals with numerous citations. However, they were unable to elicit responses to that part of their questionnaire seeking specific examples of how respondents applied their training. It is likely that poor question design was partly responsible. Further experimentation is required in eliciting this type of more objective if somewhat anecdotal evidence of the impact of formal training.

According to VLS/VDSA sources, 53 people around the world have used VLS data in their PhD and Masters dissertations. Thirty eight people have used the data as the basis of their PhDs. The PhDs were distributed across 14 research areas but not unexpectedly, production economics was the research area where the largest number of PhDs was undertaken.

New methods and theories

The impact of the databases on the development of methods and theories is well known. In a thirty-year, retrospective comparison of the changes in living standards in the six VLS villages, Stefan Dercon of Oxford University and his co-authors (Badiani et al. 2007) summed up that impact as follows:

'It is hard to think of any other data set in development economics that has been as influential as the village level data collected between 1975 and 1984 ... Even though only 240 households were covered by the core data set...some of the most influential articles in empirical development used this data set, on themes such as nutrition, technology adoption, tenancy contracts, activity choice, consumption smoothing or risk sharing. Many stylized facts about the microeconomics of development appear to stem from these villages. Take a random published empirical paper dealing with the microeconomics of development written between 1985 and the mid-1990s and the odds are that it will be a paper on these six villages (Badiani et al. 2007, p.1).'

Using Google Scholar, the VDSA team identified 290 papers referring to the VLS/VDSA projects that had been cited elsewhere at least once. The total number of citations to this set of papers was 34,420 as of 28 October 2014. Five of the papers have been cited more than 1,000 times.

A subset of 143 journal papers (listed in Appendix 15.3) has been classified into 14 research areas. This set of papers has been cited almost 30,000 times. The research areas of risk and uncertainty, production economics and efficiency analysis, where early use was made of the unique time series and cross section characteristics of the data, account for over 20,000 of the citations. I can't

empirically value the contribution of this body of research to the world stock of scientific knowledge but the large number of citations attests that the unique panel dataset has allowed research, which has been highly influential across a range of research areas.

A selection of advances in theories and methods first allowed by the VLS are reviewed in Section 9 and some are briefly summarized here. The findings of the risk and uncertainty research (section 9.2) were that 'when payoffs are fairly high, farmers typically are moderately risk averse, with very few farmers being extremely risk averse and none being risk preferring' (Binswanger-Mkhize (2013), p.63) irrespective of size and other differences between farmers. In related research by Pender (1996), farm families were found to have very high discount rates and faced extreme liquidity and credit constraints. These understandings about the attitudes of farm families to risk and their rates of time preference are likely to have influenced the direction of agricultural research and farm policy in India and elsewhere. The major contribution from this research was the finding that households are able to self-insure against idiosyncratic risks but not systemic or covariant risks. They found that the burdens on poor families from major weather and price disturbances are too onerous for the usual informal risk diffusion mechanisms operating at the village level (especially with the decreasing availability of common property resources). These burdens generally meant that poor farmers made suboptimal use of inputs and capital items. Moreover, covariant risk and moral hazard makes it difficult to devise viable insurance mechanisms and rural credit facilities. The implications of these findings are that social safety net programs should focus on ameliorating covariant risk[2].

The VLS project facilitated the first comprehensive study on common property resources (CPRs) in India (Jodha (1986, cited 753 times)) that found that CPRs contributed significantly to the income and nutrition of lower income groups in the VLS villages and allowed consumption smoothing over poor years (section 9.3). Elinor Ostrom (1990) cited Jodha's work, in her Nobel Prize winning work on "Governing the Commons" from 1990. Perhaps this work has slowed the alienation of CPRs.

Battese and Coelli (1988 and others) have had a broad ranging influence on the way panel data methodologies are used to measure efficiency and the impact on economic policies on households and firms over time that extends well beyond SAT households (section 9.4). Their methods have been incorporated in all leading econometric software. These techniques are now routinely taught to econometric students throughout the world and applied to problems far removed from SAT agriculture. Their papers account for almost a third of total VLS citations. Perhaps we can think of the VLS contribution as being the earlier development of these econometric techniques but there is no obvious way of valuing this. It is also likely that the impact on SAT farmers has been smaller than that of the risk and uncertainty work, for example, because this body of work is more of the nature of a global public good. There are likely big returns to be had from restarting research in this area particularly in a state contingent framework (Chambers and Quiggin 2000).

Other areas where the contribution of knowledge has likely been significant include production economics and nutrition and gender economics (Section 9).

Accelerated technology adaptation

The technologies trialed in the VLS villages are listed in Appendix Table 15. 2. Those explained in more detail in Section 10 include the more rapid adoption of Maruti pigeonpea and watershed management. Kumara Charyulu et al. (2015) have estimated gains attributable to the VLS project from hastening the rate of adoption of Maruti in Akola, Maharahstra. They were careful to avoid attributing economic benefits to the VLS project that are rightly attributable to the pigeonpea breeding program. The VLS presence and efforts were in the villages of Kanzara and Kinkhed in the Akola district of Maharashtra. Conservatively, they attributed only the benefits from more rapid adoption of Maruti in Akola, $1.7 million, to the VLS project. The variable costs amounted to $152,814, giving a benefit cost ratio of 11.1:1, but no allowance has been made for a share of overhead costs of the VLS projects of $14.7 million. The gains attributed to the VLS project are about 2.56% of the total gains from the introduction of wilt resistant Maruti in Akola.

2. Anecdotally I have been informed that the World Bank was influenced by these findings but I have not established this.

An important area of research at ICRISAT has been watershed management. There are many components to this research program but the broad objective has been to increase yields in dryland areas, through conserving moisture, managing excess water and protecting soils. There have been several economic assessments of this program (or components of it) which indicates an ongoing relationship whereby the VLS group is likely to have influenced the direction of watershed management research. Broad bed furrow (BBF) technology was trialed in three VLS villages for about four years from 1978 that likely hastened its adaption and adoption (section 10.2) in areas suitable to the technology.

Research priority setting

There are formal and informal ways by which the VLS team is likely to have influenced the direction of research at ICRISAT and in national and CGIAR institutions. Formal influence occurs through the normal processes of reporting the impact of research through publications and seminars and as a partner in the development of research programs. However, informal influence through daily encounters between staff, particularly science managers, is likely to have been just as influential.

While the economic impact of a change in research priorities may be estimated as the gains from alternative technology sets, judging the influence of VLS research on priority setting within ICRISAT is a highly subjective or probabilistic process. The VLS research is only one source of information used by research managers in establishing their research portfolios and hence, some subjective attribution process is required if the VLS contribution is to be identified.

The ICRISAT Annual Reports provide some evidence that the VLS project was likely to have influenced the direction of research at ICRISAT. The 1981 Report in particular, contained a lengthy review by the Farming Systems and Economics Research Programs of the previous six years of research into watershed research and farming systems. A range of technologies were evaluated for their potential for adoption by SAT farmers, and in many cases, the assessments were based on VLS data and village experiences.

Areas where the VLS/VDSA projects have been influential in setting research directions in ICRISAT and elsewhere, such as in the CGIAR, which are explained more fully in Section 11, include:

- Breeding for yield vs. protein
- Crop/livestock interaction
- Implications of farm size for technology and policy development
- VDSA influence on CGIAR CRP programs
- Intercropping research
- Herbicide research
- Watershed research
- Bioeconomic modeling

Accelerated rural policy development

Policy makers take advice from many government and non-government sources. Identifying which sources have been influential is a highly subjective process. Many of the intermediate outcomes from VLS/VDSA activities have policy implications. However, those analyses that exploit the unique panel data characteristics of the VLS/VDSA databases allowing a better understanding of how rural households manage weather and price uncertainty, as distinct from descriptions of trends in welfare that are discontinuous in time and between households, ought to have been more influential in policy areas seeking to mitigate uncertainty and reduce poverty.

Areas where the VLS/VDSA activities are likely to have had some influence on rural policy development include:

- Trends in the welfare of rural households
- The MGNREGA scheme and other safety net programs
- Crop insurance
- Common property regulation
- Free trade between states
- Community Driven Development (CDD)
- Land economics

Deb et al. (2014) is a good recent example from a set of papers that have reported the trends in the welfare of rural households based on VDSA data. It provided detailed trends in income and poverty for different occupational categories of rural households that showed considerable gains in most villages. These studies have shown that per capita real income has rapidly increased and poverty reduction was faster in the 2000s. Income sources have diversified with more income from non-farm sources. The studies have also documented rapid transformation in rural economies. However, the influence on policy of this set of papers is difficult to identify. While comprehensively tracking trends in important parameters from a household and village perspective, I have not been able to assess whether the VDSA findings are different to those from other sources. However, the publication record based on the VDSA databases and the associated symposia (Table 11) attracting key policy makers suggest that this research in tracking household welfare and poverty, in addition to adding to the stock of scientific knowledge, has likely been influential with policy makers.

This set of papers may form a platform for a more analytical program of research (either within the VDSA team or externally) fully exploiting the panel data properties with clear policy implications in areas where household behavior with respect to risk, for example, is critical to policy design. Efforts in this area are underway as evidenced by the set of papers dealing with social safety net programs.

The VLS/VDSA team and partners have had a long standing interest in evaluating the impact of some of India's social safety net programs such as the MGNREGA scheme (the Mahatma Gandhi National Rural Employment Guarantee Act) and its predecessor at a state level, the Maharashtra Employment Grant Scheme (MEGS). Binswanger-Mkhize (2013, p. 65) pointed out that from the earliest days of the VLS project, household data were being used to demonstrate the impact on households of the MEGS scheme (Walker and Ryan (1990)). This type of analysis has continued also in the second generation VDSA project with external support. Several journal papers have used the panel data to examine the impact of MGNREGA on issues such as rural wage rates, household welfare, and access and efficiency issues. The results suggest that MGNREGA is an important source of support for the program participants, especially for those from poorer households and for women or the elderly who cannot seek work away from the village. I have made no attempt to survey the literature to see whether this analysis of MGNREGA is providing a different viewpoint to the large literature in this area.

Investment in the VLS and VDSA projects

The investments in the direct outputs and intermediate outcomes of the VLS and VDSA projects were estimated. However, one difficulty faced during the estimation was that there were no financial records of investment in the VLS project. Those who worked on the project were surveyed for the time they spent on the project. Estimation procedures are described in Section 5. A distinction was made between investment in the direct outputs – the database and the VLS infrastructure – and the intermediate outcomes.

Another difficulty faced was that no information was available on the investment by those partners who used the VLS data and infrastructure to generate the intermediate outcomes but it is likely to have been many multiples of the VLS investment. In addition, it was difficult to identify all those who have used the data since the data has likely been shared widely.

	Direct Outputs US$ million	Intermediate Outcomes US$ million	Total US$ million
Generation 1	14.7	12.4	27.1
Generation 2	7.7	5.1	12.8
Total	22.4	17.5	39.9

In present value terms, the investment in both projects has been about $40 million with about 2/3 going to the first generation VLS project. A little more than half of the investment in each project has gone on assembling the databases and the village infrastructure.

Future benefit flows

Predominantly, the actual, as distinct from potential, impacts identified in this report can be traced back to the original VLS project. A number of factors explain this. The focus of attention of the VDSA, as required by the Bill & Melinda Gates Foundation contract, has been to extend the data gathering to new villages in East India and Bangladesh, requiring the training of a new team of village investigators and support staff. The meso databank has also been extended. Considerable effort was also required to make the data available in a user friendly format at a website and through an on-line knowledge bank that has some interactive analytical capabilities. It seems that the objectives of the Bill & Melinda Gates Foundation VDSA project have been largely met.

Another reason is that, as typical for much research, there are long lags between the collection of the data, potential users becoming aware of its availability and subsequent analysis of data and publication of findings. Many of the highly cited publications from the original VLS project did not become available for a decade or more after the project concluded. Moreover the success of the original VLS project can be partly attributed to the outstanding team of economists engaged in the project, which is an uncommon occurrence.

Analysis of the VDSA data has already yielded important insights into trends in the welfare of families in SAT India, east India and Bangladesh (section 13). Studies have been carried out to describe trends in household income and poverty, changes in cropping patterns and farming systems, the impact of social safety net programs on wage and labor markets, and trends in gender, nutrition and health parameters. This work has been reported in an array of early stage research and communication activities, detailed in Tables 8 – 10, which underlie expectations of future project impacts. There have been over 270 papers including 9 journal papers from the VDSA team and a strong training record. As mentioned in section 12.1 and detailed in Table 11, the team has worked with partners to hold conferences and symposia attracting key policymakers especially from India, increasing the likelihood that its analyses will be influential in creating awareness about the potential of the VDSA databases.

A weakness of this current impact assessment process is that I have not attempted to clearly identify, in an ex ante sense, specific research areas or projects of existing users of the VDSA databases, e.g., the PhD students, which are likely to have a significant impact in the future. However, the same set of four factors, listed earlier, that I have used ex post to identify activities likely to be of high impact, can be used to assess ex ante, the likelihood that activities will be influential in coming years.

The challenge for the VDSA team is to ensure that the potential of the VDSA databases and infrastructure to deliver strong gains in economic and social welfare, including additions to scientific knowledge and capacity, are realized. There are some obvious research opportunities for the VDSA team and social scientists around the world. It is highly likely that the flow of benefits will be larger for research that exploits the cross section and time series nature of the data. These opportunities (perhaps too strongly reflecting my interests in production economics) include:

- Empirically testing new theories, such as the state contingent approach of Chambers and Quiggin (2000), about how economic agents make decisions under risk, an area of research where the original VLS project had a major impact;
- Using the data to estimate productivity growth in regions covered by the VDSA project and decomposing this productivity growth into components such as technical change and technical efficiency (following O'Donnell, 2010, 2011 and 2006), which give insight into the potential role of research and extension services in promoting efficiency. The data have not previously been used to address these questions;
- Exploiting the panel nature of the data to continue research into how household nutrition and gender issues are influenced by variability in weather, markets and off-farm employment and constraints in factor markets; Continuing the work to develop representative farm models based partly on VDSA data that allow the impact of potential technologies and rural policies to be simulated;
- The villages still provide a research environment with a household perspective to trial technologies. This capacity is not being used to the extent it was under the VLS project but the opportunities are still there.
- The VDSA villages still provide the infrastructure for special purpose surveys and analyses including baseline data extending back to the 80s.

As in the past, much of the research program will be undertaken by scholars around the world. However, the VDSA team does have an important role in making scholars and policy makers aware of the potential of the VDSA databases and infrastructure that extends far beyond the development of a database. Their achievements in holding conferences and symposia in India, described in Table 11, is important, not only as a vehicle for presenting results of analysis but also as a vehicle for promoting awareness of the databases and infrastructure. Similarly presenting papers at international conferences promotes awareness.

Perhaps future promotion activities should include targeting universities and research institutions throughout the world that have strong capacities in areas such as production economics and risk and uncertainty. There may be benefits for the VDSA team, especially in terms of capacity building, from seeking a formal alliance with one or more of these institutions to ensure that achieving the potentially high impact outcomes from the VDSA projects is not left to chance.

Concluding comments

Assessing the impact of the VLS/VDSA projects has been a difficult task. One reason for this has been that the databases, which are their most significant direct output, have been used in so many ways. It has been well beyond the resources of this assessment report to follow all these paths to impact and so I have had to use judgment and the opinion of those familiar with the projects to identify the sample of impact pathways reported here. It is likely that some that I have overlooked have had significant economic and social outcomes, just as it is likely that the impact of some of the pathways I have followed has been minimal.

I have had to resort to probabilistic statements about likely impact because many outcomes, those where the outcomes are in terms of new scientific knowledge and/or capacity, cannot be valued easily using standard economic welfare analysis traditionally applied to new technologies or policy shocks – a second reason for the difficulty of this task. Nor have the resources been available to apply welfare analysis to more than the Maruti adoption activity.

A third difficulty is that my expertise does not extend across all the research areas to which the VLS/VDSA databases and infrastructure have been applied. I had for example, read very little in the areas of common property resources, and gender and nutrition economics and even in those areas with which I had some familiarity, judging whether a particular piece of research had been influential relative the rest of the literature in that area was not something I was comfortable about.

A fourth difficulty, is that particularly for the VDSA project, many of the outcomes will accrue in coming years and some are unforeseen at this time.

The publication record from the VLS project has been strong with over 30,000 citations to 143 journal papers. Moreover the bulk of these citations have been to papers in the areas of risk and uncertainty, production economics and efficiency analyses that would not have been possible without panel data. The bulk of PhDs using the VLS/VDSA databases also fall in these categories. There have been other highly cited papers in the areas of common property rights, land tenancy, gender and nutrition which have used the databases and the village infrastructure to test hypotheses counter to the conventional wisdom. The gains in economic welfare to households from trials of some technologies exploiting the whole farm perspective allowed by the village infrastructure are likely to be large, as evidenced by the one technology quantitatively assessed here - the gains in welfare in the Akola district from the more rapid adoption of Maruti pigeonpea. Examples where analyses based on the VLS databases and infrastructure were likely to have influenced research priorities at ICRISAT and elsewhere, and rural policy were also identified.

In my judgment, the gains in economic and social welfare eventually deriving from these outcomes are likely to have exceeded the $40 million investment in the projects many times over. For those activities with a predominantly SAT focus, such as the more rapid adoption of Maruti pigeonpea, the gains in welfare have accrued first to rural households in the SAT but are likely to have been shared with consumers through normal market processes. However, the better understanding of how rural households make choices when weather and prices are uncertain and about the markets in which they operate, have likely influenced the welfare of rural households in many other parts of the world. The VLS/VDSA projects provide global public goods deserving global community funding.

The challenge for the VDSA team now is to increase the flow of future benefits from the VLS/ VDSA databases and infrastructure by its own research efforts and by promoting the attractions of the databases to external scholars. Areas of research exploiting the unique features of the VDSA databases and infrastructure were identified above.

The investment by ICRISAT management in this assessment process has been $60,000 for 80 days of work and travel. Not unexpectedly, I have spent closer to 150 days on this project and still was unable to adequately pursue enquiries in some areas (noted in the report) that might have more firmly established whether they had been influential. It is unrealistic of science managers (not just those at ICRISAT) to expect credible impact assessments of large projects like the VLS/VDSA for paltry investments. Further, resources could be used to establish and measure impact in some areas identified in the report to give greater credibility to my judgment that the investments in the VLS/VDSA projects have been well worthwhile. However, these resources might better be used to promote the use of the databases and VLS infrastructure and secure a flow of future impacts that presently are in the realm of potential rather than realized outcomes.

1 Introduction

There are two eras or generations in the history of the Village Level Studies (VLS) project. The first generation covers the time from its inception in 1975 until 1984 and was known as the VLS project. In the second generation, the VLS project was resurrected as the Village Dynamics in South Asia (VDSA) project in 1999. A more detailed timeline for the projects can be found in Appendix 1.

1.1 First generation VLS project

In 1975, the first generation of the VLS project started with six villages and 240 households. A feature of the project was that the household data were collected by full-time investigators who lived in the villages. In 1980, four more villages were added in India giving a total of 400 households. Another 10 villages (250 households) in Burkina Faso and Niger were studied in the 1980s.

According to Walker and Ryan (1990, pp 9-10), three factors influenced the decision to collect data from a large sample of households in the semi-arid tropics (SAT) of India. First, the databank allowed economists to efficiently meet the needs of biological scientists seeking to understand how potential technologies might be received by SAT farm households leading to more efficient use of limited research resources. Second, because of the highly variable production environment of the SAT, some questions related to yield and income instability could best be addressed using a panel dataset. Third, there were other questions of interest to social scientists and others concerning economic development where using a common panel dataset allowed complementarities between the research areas to be captured.

1.2 Second generation VDSA project

Data were not routinely collected from the VLS households after 1984 (largely for budgetary reasons) although the Indian households were resurveyed in 1989 and there were several special purpose surveys including one on nutrition in 1993. The project was resurrected in 2001. In this second generation, funding initially came largely from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) sources complemented intermittently by funds from USAID, the UK Overseas Development Institute (ODI), the World Bank, Oxford University, and the EU. In 2009, six years funding amounting to $9.95 million were obtained from the Bill & Melinda Gates Foundation for the implementation of the VDSA project in 42 villages of India and Bangladesh.

While the project was still based on establishing a panel dataset, there was a change in emphasis on how this dataset was to be used. There was a stronger emphasis on using the dataset to trace out how the welfare of poor SAT families changed over time and to use the dataset to assess the impact of changes in economic policies and conditions on poor families. The goal of the VDSA project is to enhance the productivity, welfare and sustainability of rural households and the village economies in South Asia by 'raising voices of the poor'.

Partners in the project funded by Bill & Melinda Gates Foundation included ICRISAT, the International Rice Research Institute (IRRI), Indian Council of Agricultural Research (ICAR) institutes (National Centre for Agricultural Economics and Policy Research—NCAP, New Delhi; ICAR Research Complex for Eastern Region, Patna; Directorate of Water Management, Bhubaneswar) of India and other research organizations and state agricultural universities in India and Bangladesh.

A central argument in the proposal was that 'the capacity for improving pro-poor technological, institutional, and policy design was limited' without high frequency time series and cross-section data at the household level. The aim of the Bill & Melinda Gates Foundation's proposal was 'to sharply increase the availability of relevant data for decision making on development issues so as to reduce impoverishment in poverty-laden regions in the semi-arid and humid tropics of South Asia. The objectives are given below:

Objective 1: Enhancing the availability of reliable household-, individual-, and field-specific, high-frequency, time-series data in purposively selected villages in the semi-arid and humid tropics of South Asia

Objective 2: Increasing the availability of updated and expanded meso-level (e.g., district-level) agricultural data in India and Bangladesh; and

Objective 3: Nurturing policy analysis and strengthening capacity building to fully exploit the data collected and assembled in objectives 1 and 2.'

The Bill & Melinda Gates Foundation funding allowed the survey to be scaled up to 1,824 households in 42 villages – 18 villages (864 households) in the dryland tropics of India and 24 villages (480 households) in the humid tropics of Bangladesh and East India. The African villages were not routinely surveyed but were part of special-purpose surveys. The long series of panel data (back to 1975 for 6 villages) allowed the income and consumption experiences of individual households to be tracked that are otherwise lost when data are collected at higher levels of aggregation.

The Bill & Melinda Gates Foundation funding was also used to assemble meso level data at district and state levels on key agricultural and economic statistics. Surveys of nutrition and women's empowerment were undertaken in 2013-2014.

These datasets have the characteristics of global public goods. A key characteristic is that information is non-rival in consumption or, in less technical terms, the use of the information by one person does not reduce the amount of information available to the next user. This characteristic is a source of economic growth. Another characteristic of public goods is that it is difficult to exclude those who do not pay for the data. Some institutions charge fees to access the databases they maintain. Inevitably this denies access to some who could make good use of the data but who do not have the resources to pay these access charges which bear no relation to the low cost of providing the data to these users. A more efficient solution is to make the data freely available but fund it in some collective manner. Because the findings from research using this data have application across the world, and not just in SAT India, there would likely be underinvestment in assembling this data were it left to Indian institutions. It has to be funded globally and this has been the case.

1.3 Objectives of and methodology used in this report

Few attempts have been made to systematically assess the nature and extent of the use of VLS data by different user groups, such as researchers, policy makers, and students, and trace the many outcomes of the project on the welfare of farmers in the SAT and its global contribution to human scientific capacity. This is a challenging task given the many pathways by which the projects have potentially had an impact, but it is important to identify the economic and social outcomes to ensure decisions about continued funding of this project are based on an understanding of its impacts.

The objectives of the present report have been:

- To identify the direct outputs of the projects and the set of intermediate outcomes derived from the direct outputs by scholars around the world and the VLS/VDSA team;
- To identify and describe the paths by which these intermediate outcomes have resulted in changes in economic and social welfare and increases in scientific knowledge and capacity;
- To assess the likelihood that some of the intermediate outcomes have made significant contributions to economic and social welfare and to scientific knowledge and capacity;
- To estimate the investment by ICRISAT and partners in the VLS/VDSA projects;
- To estimate the economic gains from the VLS contribution to bringing forward the adoption of Maruti pigeonpea in Akola and neighboring districts in Maharashtra;
- To conduct a tracer study of learner participants in the VLS/VDSA projects to assess not only the capacity built from their time in the projects but also how they used this capacity subsequently.

The best outcome from this impact assessment process would have been a quantitative estimate of the economic benefits attributable to the VLS/VDSA projects which could have been compared to the investment in the project led by ICRISAT and many others who have used the databases – or at least the empirical assessment of enough outcomes such that the benefits of this sample exceeded the total investment in the VLS/VDSA projects. An empirical evaluation of the contribution of the VLS project to the more rapid adoption of Maruti pigeonpea in Maharashtra is reported below and is an example of the empirical impact assessment anticipated.

However, there are likely to be a large number of small impacts. Perhaps many could be traced through to shifts in supply that could be evaluated using standard welfare analysis but the costs of such an exercise necessary to identify and estimate enough benefits to offset the entire investment in the VLS and VDSA outputs and outcomes by the projects and perhaps larger investments by partners are daunting and certainly beyond the capacity of this report.

Moreover, many of the most significant impacts of the projects are likely to have been the new knowledge generated from the analysis of the data and the gains in human capacity from training experiences associated with the projects. There are no practical ways of valuing these gains except through tracing how the knowledge and capacity has been applied in particular situations.

The goal has been evidence based, replicable assessments (even if unquantified) of the many impacts of the VLS/VDSA projects by justifying plausible causal links between inputs and outputs along the impact pathway. Why farmers adopt particular technologies, why science managers choose particular projects, and why policy makers adopt particular polices are all difficult to discern. Hence, while care has been taken in attributing influence to results emanating ultimately from VLS/VDSA outputs, all of these statements are probabilistic or subjective.

In the course of this impact assessment, I developed a set of factors to guide my judgment about whether the project activities are likely to have been influential. These factors are as follows:

- Whether they have used the unique time series and cross-section characteristics of the data to analyze the choices by rural households when weather and prices are uncertain;

- Whether they have used the village infrastructure allowing technologies to be trialed, special surveys to be conducted and sensitive data to be collected accurately;

- Whether the village household perspective they provided was not otherwise available (although I was unable to assess this in many instances);

- Whether they have exploited these three factors to test hypotheses that challenged the conventional wisdom about the consumption and production choices of rural households and the behavior of markets in which they operate, whether they provided new information in other words.

In many instances, I have not had the time to review the literature to assess whether project activities have provided any new information. This shortcoming has often been noted in the report. Nor should this report be interpreted as an exhaustive review of all project activities. The focus of this report is on those activities that were likely to have been influential.

The next section provides a schematic representation of the classes of initial direct outputs from the projects and then of the intermediate outcomes arising from the direct outputs with further investment by partners of the VLS team throughout the world. In section 3, a more formal heuristic approach is used to describe the paths by which these intermediate outcomes have an impact on the productivity and profitability of farmers. Section 4 presents a methodological framework suitable for evaluating (or at least conceptualizing) many of the economic impacts from VLS/VDSA activities. Section 5 focuses on the investment made by the VLS and VDSA teams. Sections 6 and 7 present more details about the direct outputs of the projects – the databases and the infrastructure, allowing a range of special purpose surveys and studies including an ongoing study of nutrition. Sections 8 –

12 explain the five intermediate outcome groups in more detail. Some activities within each group that are likely to have been influential are discussed in terms of their impact and the evidence for these outcomes. In Section 13, it is recognized that while the present VDSA project has focused on the processes for streamlining the collection and dissemination of data from a much expanded set of villages, impacts are beginning to emerge. In this section, the VDSA activities are described and how the team might increase the flow of high impact outcomes are considered.

2 An impact pathway for the VLS and VDSA projects

2.1 Introduction

Lessons from past impact assessment studies indicate that an important early step in the assessment process is to develop a clear and detailed picture of the research process, from the development of the project to its final impact. This requires the development of a research impact pathway. The need for a clear impact pathway has been championed by ACIAR, and all its impact assessment reports are required to contain an impact pathway diagram (Davis et al. 2008). Developing a clear impact pathway is good practice in any thorough benefit cost analysis.

The ACIAR framework and reports provide good examples rather than a recipe for good practice. Each project has peculiarities and thus needs to be represented by its own unique impact pathway. The intent of an impact pathway diagram is to give a sense of the direction and content of an accompanying narrative about how the impacts of inputs committed to an R&D program are to be traced, through sometimes many intermediaries to final outcomes and then impacts.

Describing the pathway by which a traditional production agriculture technology, such as a new crop variety, is finally expressed in increased income for farm families is relatively straightforward. After research and extension phases, the new technology is adopted over time by farm families if it increases their yields, lowers their costs or has some other benefit to their farming system (most of which can be valued in markets). These changes are reflected in higher incomes.

It is more difficult to trace out the pathway of impact of a socio-economic project such as the VLS project because of the following reasons:

- The first outputs of the VLS program have been used in many applications each of which could be represented by a unique impact pathway;
- At least some of the final outcomes such as new knowledge and skills are not immediately reflected in supply shifts but are the building blocks for later sources of productivity gains;
- The value of some VLS outcomes lies in the extent to which they bring forward the adoption of efficiency gains, which may largely be generated by a cooperating program such as a crop breeding program. Only a share of total benefits can be attributed to the VLS, and this requires a subjective judgment based on the opinions of those closely involved in the development, adaptation and extension of the technology.

Figure 1 presents a conceptual pathway by which the resources available to the VLS program (at the top of the flowchart) have contributed to the final economic, environmental, and social impacts and gains in scientific knowledge and capacity (at the bottom of the flowchart).

2.2 VLS/VDSA outputs

The two broad classes of immediate outputs from this set of VLS inputs included:

- The household panel and meso-(district, state) level databases;
- An infrastructure for farming systems research, community development projects, and special purpose surveys.

A key objective of the VLS program was ‘raising the voices of the poor’. The household database across villages and through time provides a unique way to hear the impact on the poor of new technologies, some developed at ICRISAT, and of rural policies and to monitor the impact on them of changes in the economic and social environment in which they are situated. Similarly, the VLS infrastructure in the villages was designed so as to allow the experiences of individual rural households to be ‘heard’. Ultimately, the present report tries to determine whether this attention to cross-section and time series data has enhanced the welfare of SAT households through its many impact pathways.

VLS/VDSA PROGRAM

"RAISING THE VOICES OF THE POOR"

DIRECT OUTPUTS

Household and Meso-level Panel Databases

Infrastructure for Farming Systems Research, Community Development Projects & Special Purpose Surveys

IDENTIFICATION OF APPROPRIATE COUNTER FACTUAL

Adoption and Investment by Next Users

INTERMEDIATE OUTCOMES

Capacity Building through Training

C_t

- Capacity of scientists
- Capacity of VLS households
- Capacity of Institutions

New Methods and Theories

L_t

- Analysis of risk &uncertainty
- Analysis of common property Issues
- Efficiency analysis
- Production economics
- 10 other areas

Program Priority Setting

Z_t

- Yield vs. protein
- Crop/ Livestock Interaction
- Farm size and technology
- CRP crop programs
- Intercropping research
- Herbicides R&D
- Bioeconomic modelling

Accelerated Rural Policy Development

J_t

- Trends in household welfare
- Assessing impact of SSN programs
- Crop Insurance
- Common property regulation
- Free trade between states
- Community Driven Development

Accelerated Technology Adaptation

K_t

- Faster adoption of Maruti pigeonpea
- Watershed research

ADOPTION THROUGH CHANGE AGENTS

Enhanced skills from Capacity Building

Dissemination of new methods and theories

Extension of Farming Systems Management

Contribution to Policy Change

IDENTIFICATION OF APPROPRIATE COUNTER FACTUAL

FINAL IMPACTS FROM CHANGED PRACTICES

Scientific Knowledge & Capacity

Economic

Environmental

Social community

Figure 1. VLS/VDSA Impact Pathway.

2.2.1 VLS and VDSA databases

The most obvious output from the VLS/VDSA projects has been the rich panel datasets of key economic and social parameters by household through time. The value of these datasets in allowing changes in economic circumstances of households to be traced over time and providing a snapshot of current circumstances was greatly enhanced with the second generation phase of the project. Two databases, the household-level panel database and the meso-level database on agriculture, are now maintained and shared with the global community through the VDSA website (http://vdsa.icrisat.ac.in). More details about how the databases are assembled and used can be found in Section 6.

2.2.2 Infrastructure for farming systems research, community development projects and special purpose surveys

A second less obvious output from the VLS project is the close spirit of cooperation between the VLS households in each village and the resident investigator and other members of the VLS team. This gave rise to an environment or infrastructure where other scientists could test the feasibility of new farm technologies and rural policy and community development programs and conduct special purpose surveys. As a result of this environment where there is interaction between farmers and scientists over several seasons, it is plausible that farm technologies and rural policies that enhance the welfare of rural households have been identified earlier and adapted and adopted more quickly than otherwise. Viewing these technology and policy shifts from the viewpoint of rural households rather than from the more limited perspective of an enterprise also increases the relevance of the experiments and accelerates their adoption. The infrastructure not only provides a cost effective means of conducting special purpose surveys but the databases provide baseline measures of key parameters. More details on how this environment or infrastructure has been used in conducting special purposes surveys can be found in Section 7. The infrastructure has also been important in some of the other intermediate outcomes, and therefore, its role is described more fully when discussing these outcomes.

2.3 Intermediate outcomes

'Intermediate outcomes require additional investment to generate changes in practice, products or policy that have community outcomes' (Davis et al. 2008, p.22). There are a wide range of intermediate outcomes associated with the VLS/VDSA projects. These outcomes required inputs from other programs (new seeds, other inputs, scientific management, travel, etc.), individuals (scientific capacity), and farm households (in hosting trials). Hence, the proportion of outcomes attributable to the VLS program is not always clear. There is no one-to-one correspondence between any of the two outputs and any of the intermediate outcomes. The databases, for example, when used by cooperating projects could contribute to any one of the intermediate outcomes. Similarly, any one of the intermediate outcomes may require the use of both the VLS outputs in a cooperating project. Moreover, the elements of five general types of intermediate outcomes are not mutually exclusive, and the allocation of particular elements to any one category is somewhat subjective.

The VLS projects used some resources to generate awareness and uptake of these outputs.

Five general categories of intermediate outcomes have been identified (Figure 1):

- Capacity building through training
- New methods and theories
- Accelerated technology adaptation
- Research priority setting
- Accelerated rural policy development

In the below sections, some well-known examples for each of the categories have been listed. These sections also define the five intermediate outcomes and describe the pathway by which they feed through to the final impact. These outcomes are briefly described below but more detail about individual intermediate outcomes is provided in Sections 8 - 12.

2.3.1 Capacity building through training

Over 200 people have invested in formal and informal training from VLS staff using some combination of the VLS outputs above. 'Capacity building encompasses training and all other forms of learning that enhance the knowledge, understanding and competencies (skills) of individuals (Gordon and Chadwick 2007, p.18)'. Gordon and Chadwick (2007) distinguished between human capital and the stock of knowledge (e.g., from R&D). They reported that human capital alters the 'enabling environment' and 'strengthens institutions' in a way that 'mere' knowledge does not.

As part of this assessment project, a tracer study of the people who have received formal training from VLS staff has been conducted. One of the objectives of this study was to invite the respondents to clearly state the ways by which VLS training was of value to them and how it changed either the process or outcomes of their work immediately following VLS training. This study is reported in Section 8.

The VLS farm households themselves are likely to have developed an increase in capacity to respond to changes in their circumstances in addition to their gains in economic welfare from being early adopters of new technologies.

2.3.2 New methods and theories

The unique panel data characteristics of the VLS database have meant that it has been extensively used to test hypotheses empirically; for example, about how farmers respond to risk and uncertainty, about the efficiency of agriculture and the importance of common property resources. These analyses have sometimes led to advances in empirical techniques such as stochastic frontier analysis. Rural households face great variability in income from weather and markets. Hence, both cross section and time series data are required to help describe and understand how households manage this uncertainty. The VLS database was the only such database available at that time. There are some alternatives now but, as described below, the VDSA databases still have features that are not available elsewhere.

In Section 9, the following areas where the use of the VLS data has contributed to theoretical and/or methodological advances are described more fully:

- Review of the impressive publications and PhD record from the projects
- Analysis of risk and uncertainty
- Analysis of common property issues
- Efficiency analysis
- Production Economics
- Nutrition and gender

2.3.3 Accelerated technology adaptation

Critically, the program fostered a whole farm perspective in agricultural research programs (noted in Walker and Ryan 1990, p.13 and detailed in Ryan 1984). It created a research environment where technologies that were first developed at ICRISAT could be trialed and adapted in cooperation with the VLS households and the resident investigator and other VLS staff before being promoted to farming communities outside the VLS. Important examples, described in Section 10, included broad bed and furrow technology and the adoption of Maruti (ICP8863) pigeonpea in Maharashtra.

Walker and Ryan (1990, table 2.2 p.14) have reported a table that lists a set of technologies tested in the villages since 1975 (presumably to about 1990) and this list has been updated in Appendix Table 2. Over the two projects, about 26 technology adaptation trials have been undertaken; some of which were undertaken in those years between the VLS and VDSA projects and five were undertaken since the VDSA project began. Areas of technology development included the incidence of shoot fly, midge fly, *Striga* in sorghum, incidence of downy mildew, ergot and smut in pearl millet, incidence of wilt and sterility mosaic in pigeonpea, nodule counting in chickpea, pigeonpea and groundnut, weed counts, and crop rotation information.

While accelerated technology development was a strong focus in the first generation of the VLS project, it became less important in the second generation although work with pigeonpea and more recently groundnut has continued. An important reason for this is that now ICRISAT scientists have much greater ability to work with scientists in national agricultural research systems (NARS) including universities, and these links have been used in place of the VLS villages to promote the development and adoption of new technologies. It is not clear that these new arrangements match the strong advantages of the VLS project in providing a whole farm/household perspective over several years. There seems to be a continuing opportunity to use the VLS/VDSA to trial and adapt new farm technologies.

2.3.4 Improved research priority setting

There are likely to have been several pathways by which the VLS/VDSA projects influenced research priorities at ICRISAT and other research institutions in partner countries and in the CGIAR system. The use of the VLS infrastructure to trial technologies has been discussed. The farm management and production economics research based on VLS data has also likely influenced the direction of research. However, the daily interactions between the VLS team and scientists and research leaders at ICRISAT have arguably been as important, if not so obvious. Areas where the VLS project has been influential in setting research directions in ICRISAT and elsewhere are given below (Section 11 discusses them in detail):

- Breeding for yield vs. protein
- Crop/livestock interaction research
- Implications for farm size for technology and policy development
- Watershed research
- CGIAR CRP crop programs
- Intercropping research
- Herbicide research
- Bioeconomic modeling

2.3.5 Accelerated rural policy development

In a way similar to their impact on technology adaptation and research priority setting, the VLS/ VDSA projects are likely to have had an impact on the direction of rural policy, particularly in India and partner countries. However, some of the general findings about the behavior of small poor farmers in the face of weather and market uncertainty have likely influenced rural policy more widely. The databases have been used to simulate the impact of potential policy changes on actual farm households. In particular, trends in key welfare measures such as income, consumption and net wealth have been traced over time and the impact of social safety net programs such as MGNREGA have been assessed. The infrastructure provided by the projects has enabled trialing of policy initiatives such as the Community Driven Development (CDD) projects.

The interests of many groups and institutions influence the final outcomes of policy making processes. We can only guess at the influence of particular inputs into the processes and hence any statements about the likely influences of the VLS/VDSA projects, while made in the knowledge of the unique perspective of analyses based on the VLS/VDSA databases, remain probabilistic or subjective.

VLS contributions to rural policy development, described more fully in section 12, include:

- Trends in the welfare of rural households;
- The MGNREGA scheme and other safety net programs;
- Crop insurance;
- Common property regulation;
- Free trade between states;
- Community Driven Development (CDD) and
- Land economics.

2.4 VLS adoption through change agents

Several mechanisms or change agents were used singly or in combination to transfer these intermediate outcomes into the 'hands' of the final users. Some technologies such as a new variety with disease resistance are embodied in an input, e.g., a seed. Technologies that are information and management based (disembodied technologies) must be disseminated through traditional extension techniques. Some outcomes were achieved through policy change and/or regulation, and some were achieved though increases in human and institutional capacity.

A key component of any impact assessment is an assessment of the rate and extent of adoption, which is a function of the type of technology or policy shock and the change agent implemented to achieve adoption.

2.5 Final impacts from changed practices

In another joint 'production' process, the change agents extend and adapt the five intermediate outcomes from VLS activities to arrive at final outcomes in the form of economic, environmental and social impacts and additions to scientific knowledge and capacity. Here, the final impacts are briefly described in general terms. Only when there is a focus on particular VLS activities can specific intermediated outcomes and final impacts be described and preferably quantified.

2.5.1 Economic impacts

Economic impacts arise directly through the adoption of new technologies and from changes in policy affecting SAT households and indirectly through the other three intermediate outcomes. These economic impacts arise from changes in unit production costs (and sometimes product prices) that are reflected in shifts in supply or demand, which can be estimated using economic welfare analysis. As part of this study, the economic impact of the VLS contribution to the adoption of Maruti pigeonpea in Maharashtra was estimated and is reported in the later sections.

2.5.2 Scientific knowledge and capacity

While some VLS activities flow directly to new technologies or policy changes, some are first reflected in the increase in the stock of scientific knowledge and human scientific capacity that can later be used to develop new technologies or effect policy change.

An indicator of these impacts is the large volume of published papers arising from the VLS project, which is described below. Through training and more informal learning, there have also been

additions to the stock of human scientific capacity. A tracer study attempting to identify how these increases in capacity have been used is reported below.

2.5.3 Environmental impacts

Some technologies and policy changes associated with VLS activities are likely to have had a beneficial impact on the flow of environmental services in the form of water and soil quality for example.

2.5.4 Social impacts

In addition to gains in scientific knowledge and capacity, other social impacts may be a greater capacity on the part of the VLS households to react to changes in their economic environment.

3 VLS and VDSA impacts and gains in productivity and profitability

One purpose of an impact pathway is to identify how research activities bring forth changes that result in, say, a change in agricultural output (or more generally, in society's welfare).

Research institutions such as ICRISAT typically invest in activities across a spectrum, including pure and applied research, policy research and development, and extension and human capacity building, in pursuit of economic, social and environmental benefits. Many of these activities are directed at improving productivity. Productivity growth provides little advantage to a farm business unless it results in increased profitability. Thus, a starting point is to understand the relationship between farm productivity change and profitability.

Profitability, the ratio of growth in income to growth in costs, can be represented as (O'Donnell 2010):

$$PROF = \frac{PQ}{WX} = TT \times TFP \quad (1)$$

Intuitively, an index of value, *PROF,* is equated with a quantity index, *TFP*, times a price index, *TT*, the terms of trade, which is the ratio of *P,* prices received for outputs to *W,* prices paid for inputs[3]. Growth in productivity only translates directly into growth in profitability if the terms of trade are constant. Further, changes in the terms of trade may induce changes in farm enterprise mix and scale and hence, productivity. All types of economic shocks impact on the terms of trade but more relevant to our purposes, research activities that lead to price changes from say, a change in policy or long run improvements in productivity, also have an impact on the terms of trade and hence, profitability. Turning to total factor productivity, research and extension activities add to various stocks of capital which provide annual flows of services which impact on final output along with conventional inputs such as labor and chemicals. These joint changes in the stocks might be represented heuristically in a research production function (adapting Alston et al. 1995) as:

$$\left(IK_t, \mathrm{IC}_t, \mathrm{IL}_t, \mathrm{IJ}_t, IZ_t \right) = i(R_t, \ldots, R_{t-L_R}, E_t, \ldots, E_{t-L_E}; K_t, C_t, \mathrm{L}_t, J_t, Z_t) \quad (2)$$

where R_t and E_t are lagged series of research and extension investments and K_t is the stock of knowledge or new technologies available to farmers, C_t is the stock of human scientific capacity gained through formal training and learning by doing, L_t is the stock of scientific knowledge not immediately available in the form of technologies available to farmers, J_t is the stock of knowledge available to farm policy makers and Z_t is the stock of knowledge and experience of science managers in allocating research funds. The 'I' notation on the left hand side of this relationship denotes an increment in time t to these four capital stock. The relationship says that as a result of past investments in research and extension, there will be increments to these five capital stocks in time t and the size of these increments will depend not only on the level of investments but on the existing size of the capital stocks. Note that the stock of physical capital in the form of laboratories and other research inputs has been omitted in the interests of simplicity.

Equation 2 is a general form of a multi-output, multi-input production relationship where complex product transformation and input substitution possibilities are deliberately left implicit. This heuristic representation reflects the inherent jointness in the relationship where, for example, research activities not only might add to K_t but also add to C_t and L_t and training activities which add to C_t through skills gained, might also add to L_t through the development of new data analysis techniques and also, through the development of new technology, might add to K_t. No accounting system can overcome this inherent jointness and attribute expenditure among types of outputs even using necessarily subjective rules.

3. *P* and *W* are aggregate prices defined such that *PQ* is total revenue and *WX* is total costs.

How these four capital stocks grow can be represented as follows using K_t as an example:

3 $$K_t = K_{t-1} + IK_t - DK_t$$

Where DK_t is the depreciation of the knowledge stock in the present period perhaps as a technology is replaced or becomes obsolete. Similar relationships hold for the other three capital stocks. This representation is perhaps too simplistic in not explicitly reflecting the jointness between the four stocks.

The extent to which K_t is utilized on-farm depends on P_t, relative factor prices and the human capital held by farmers, H_t and can be represented as:

4 $$F_t = f(K_t, P_t, H_t)$$

The production function for final output can be represented as:

5 $$Q_t = f(X_t, F_t, W_t, A_t, J_t)$$

where current agricultural output (supply), Q_t, depends on a flow of conventional inputs, X_t, a flow of services from a stock of knowledge (or technologies) that are available to farmers, F_t, uncontrolled factors such as weather and pests, W_t, a flow of services from publicly provided infrastructure, A_t, in the form of education, transport and communications, for example, and farm policy setting, J_t. This representation abstracts from issues such as biased technical change but suits our purposes in this report. Note that Q_t and X_t are vectors of multiple outputs and inputs at time t.

Hence, the stream of investments made by the VLS program has an impact on the research production function in some combination of the following ways:

- Sometimes directly through increments to the stock of knowledge and technologies available to farmers, K_t, through advancing the rate of technology development and adoption as in Maruti pigeonpea in Maharashtra
- Indirectly through additions to the stock of human scientific capacity, C_t, through training programs and to the stock of scientific knowledge, L_t, through the development of new techniques in assembling and analyzing panel data in a risky environment, which later impacts other capital stocks;
- Directly through rural policy settings reflected in J_t, based on the use of VLS data to assess policy impacts on poor rural households but perhaps more through changes in the terms of trade;
- Indirectly through gains in efficiency in the use of research resources, Z_t, through better priority setting, for example, which are later reflected in K_t.

O'Donnell (2010) pointed out that the TFP index can be disaggregated into technical change (movement of the production frontier in response to R&D, say), technical efficiency (movement towards the production frontier in response to extension, say), and scale and mix efficiencies (movements around the production frontier) in response to price changes.

4 Estimating welfare gains from VLS/VDSA Activities

The traditional approach in evaluating the economic welfare associated with a new technology, such as a new crop variety like Maruti pigeonpea or a change in farm policy, has been to estimate the reduction in per unit production costs, k, arising from the new variety or policy change. In the case of Maruti, this estimate of k, *bc* in Figure 2, is an estimate of the vertical shift in the supply of Maruti and is the basis for estimates of the changes in the price and quantity produced of pigeonpea and associated changes in consumer (area *abfe*) and producer (area *efcd*) surplus using a standard model of the pigeonpea market. Typically, this change in potential total welfare over the target population is then scaled through time by the rate of adoption and an estimate of net present value is derived using discounting techniques.

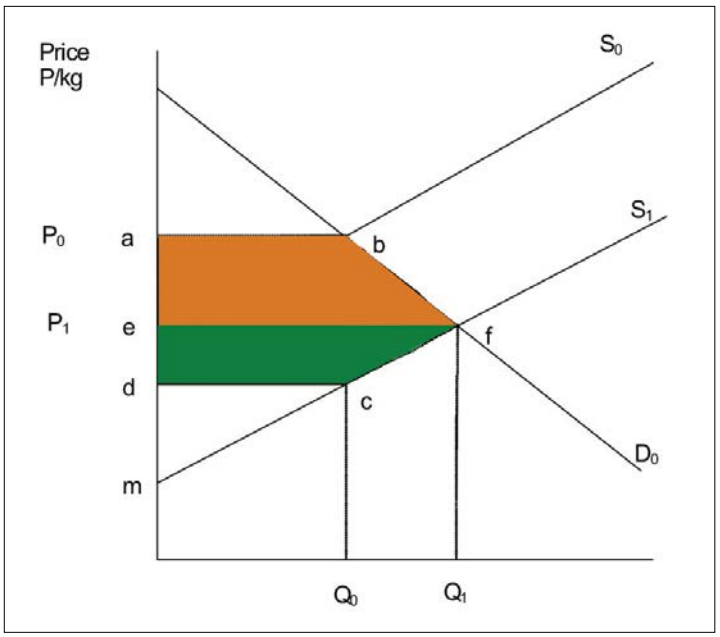

Figure 2. The welfare gains from shifting the supply of Maruti.

This approach was used by Bantilan and Joshi (1996). It is most sound when the technology has an impact on one enterprise, which is unrelated in production with other enterprises. However, many of the technology and policy examples below involve complex farming systems. In the Akola district, for example, pigeonpea is usually intercropped with soybean or cotton. Moreover, as a pulse, it contributes nitrogen to following crops. In this situation, a single enterprise market model, such as represented by Figure 2, is a crude approximation of what actually occurs.

Kumara Charyulu et al. (2015) instead estimated the change in net income from using Maruti in inter-cropping systems including pigeonpea. This change in net profit, for say, a soybean + pigeonpea system, can be estimated from a gross margin budget (income less variable costs) for a hectare of the soybean/pigeonpea system and then scaled to the target area.

Effectively, this estimate of the change in net income is area *abcd* in Figure 2, the change in unit costs, k, times Q, the size of the industry. It underestimates total welfare gains by the triangle, *bfc* which are potential gains as pigeonpea systems, now more profitable because of Maruti, are grown more widely by farmers at the expense of cropping systems that do not include pigeonpea. The area *abcd* is the total industry gains enjoyed by consumers and producers. If the price of pigeonpea does not fall much (demand is highly elastic), then most of the gains accrue to farmers.

Only a small share of the benefits from trialing and later extending technologies from the VLS villages to SAT farmers can be attributed to the VLS/VDSA village infrastructure. The contribution of the VLS/VDSA projects may be thought of as accelerating the development and adoption of a technology first developed by a breeding program, for example. Without trialing in the VLS villages, the adoption profile might look like the blue line (right most line) in Figure 3, and the area under the blue line is the extent of benefits from the technology. Trialing in the VLS villages might accelerate adoption by maybe five years. The new adoption profile is given by the red line. Total gains are now the area under the red line. The gain attributable to the VLS/VDSA infrastructure is the area (parallelogram) between the red and blue lines. If the technology is adapted and enhanced by the VLS infrastructure then the red line may be higher than the blue and the benefits attributable to the VLS are larger. As the technology becomes obsolescent, the adoption profile would turn down but this scenario is not represented in Figure 3.

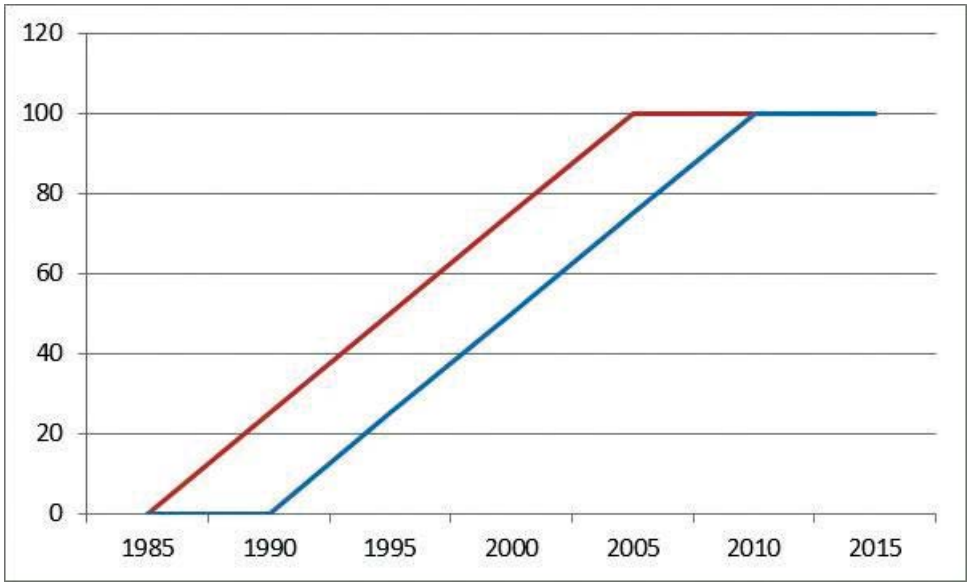

Figure 3. An accelerated adoption profile.

This concept that the VLS/VDSA projects have accelerated the development and adoption of technologies might also be useful in thinking about the contribution of the projects in some of the other intermediate outcomes. Note that applying this approach still requires estimating the total gains from the technology or policy change as well as establishing the adoption profile.

In this report, there is only one case study of the application of this methodological framework – the accelerated adoption of Maruti in the district of Akola and surrounding districts of Maharashtra.

5 Perspectives on investment in the VLS/VDSA Projects

The objective of benefit cost analysis is to relate the benefits arising from a *specific* set of inputs or resources to the value of these resources. Hence, the question of how much has been invested in the VLS and VDSA projects makes better sense when considered in the context of which benefits are being considered.

A distinction has been made between the initial outputs of the VLS/VDSA projects and their intermediate outcomes. It is difficult to estimate the investment or expenditure on these two groups. Some of these difficulties include the lack of financial records for the first generation VLS project and incomplete records for the VDSA project. There are also difficult attribution problems in assigning the time of project staff between activities involved in delivering the initial outputs, principally the databases, and in the use of this data to deliver the intermediate outcomes. Some ICRISAT staff share their time between VLS/VDSA and other research activities. No attempt has been made here to estimate the investment by those 'partners' engaged in delivering the intermediate outcomes.

The most tangible initial outputs of the VLS project are the household and meso-level databases that have been assembled. Here, it makes sense to ask how much it has cost to assemble these databases. Cost data were unavailable for the first generation VLS project but an estimate has been made of the time spent by VLS staff in setting up data collection protocols, in collecting the data, in checking data for consistency, in entering the data in databases and in making the data available to next users. The input of labor by Indian nationals has been valued at nominal wages rates for various staff classifications, converted to real 2014 rupees using the GDP deflator for India and then compounded forward to present value terms using a 5% discount rate. The total present value in rupees in 2014 was then converted to a 2014 present value in US dollars using an exchange rate of $16.67 to 1,000 rupees. There was also an input of labor by international staff (paid in $US) and this has been converted to real 2014 US dollars using a US GDP deflator. The present value of this stream of expenditure was obtained by compounding forward at a discount rate of 5%. An estimate was also made of operating costs in the form of vehicle costs, travel costs, stationary and computing costs. Their present value was calculated following the same procedure as for staff costs.

Expenditure on the initial outputs of the original VLS project can be found in Table 1 under the direct outputs columns where expenditure data is expressed in real 2014 rupees or US dollars. Note that these columns can only be summed if a discount rate of 0% is assumed. The present value in 2014 (at a discount rate of 5%)of the expenditure incurred in setting up the VLS outputs including setting up the database and collecting, processing and making the data available and setting up the infrastructure in the villages was $14.7 million (Table 3). The GDP for India and the US and the 5% compounding factors are displayed in Table 1.

There were five intermediate outcomes from using the VLS data. Each of these outcomes required further investment by the VLS team and/or investment by the next users of the data often very distant from the VLS team and larger in size. No attempt has been made to estimate investment by these 'partners' for obvious reasons.

The first generation investment by the VLS team across these five intermediate outcomes has been estimated using a similar approach to the estimation of the VLS direct output costs although much of this expenditure was in US dollars paid to international staff (Table 1). It was converted to real 2014 US dollars using a US GDP deflator from the USDA source and compounded forward to present value in 2014. Expenditure on intermediate outcomes in the generation 1 VLS project amounted to $12.4 million (Table 3). Total expenditure on the VLS project was US$27.1 million in 2014 present value terms.

Some actual data on second generation VDSA costs from 1999 until 2015 were obtained from project funding reports. From 1999 to 2008, most of the funds came from ICRISAT with small grants from USAID and ODI. From 2009, the Bill & Melinda Gates Foundation became the major sponsors of the project (US$9.95 million) with in-kind contributions from ICRISAT of about US$275,000 per year. These are expressed in US dollars and their present value in 2014 is derived by applying, first the US

Table 1. Generation 1 Expenditure by VLS team in 2014 Rupees and US dollars.

	Direct Outputs			Intermediate Outcomes		Discount	GDP Deflators	
Year	Nationals (2014 Rupees)	Operating (2014 Rupees)	I'nationals (2014 US$)	Nationals (2014 Rupees)	I'nationals (2014 US$)	Factor 5%	US	India
1974	**29,658**	4,728,759			**18,820**	**7.04**	**26.6**	6.1
1975	5,200,042	4,020,651	96,459		**41,340**	**6.70**	**29.0**	6.0
1976	3,142,461	5,137,324	29,391	2,412,391	**164,916**	**6.39**	**30.6**	6.3
1977	2,112,863	6,284,719		3,509,187	**199,868**	**6.08**	**32.5**	6.7
1978	3,312,257	7,594,241		3,411,705	**155,152**	**5.79**	**34.8**	6.8
1979	4,177,057	8,202,680		2,278,272	**185,789**	**5.52**	**37.7**	7.9
1980	9,701,018	8,883,923		2,271,511	**279,971**	**5.25**	**41.1**	8.8
1981	9,035,088	8,935,016		2,263,420	**236,029**	**5.00**	**44.9**	9.8
1982	8,775,946	9,021,559			**117,409**	**4.76**	**47.7**	**10.6**
1983	8,402,997	8,571,823			**76,645**	**4.54**	**49.6**	**11.5**
1984	8,292,473	6,289,507			**116,871**	**4.32**	**51.3**	**12.4**
1985	6,175,833	-			**118,911**	**4.12**	**53.0**	**13.3**
1986	3,617,135	-			**61,055**	**3.92**	**54.0**	**14.2**
1987	2,886,498	-			**98,324**	**3.73**	**55.4**	**15.5**
1988	2,744,331	-			**99,356**	**3.56**	**57.4**	**16.8**
1989	2,214,597	2,497,872			**99,832**	**3.39**	**59.6**	**18.2**
1990	2,281,883	2,529,914			**111,641**	**3.23**	**61.8**	**20.2**

Table 2. Generation 2 Expenditure by VDSA Partners in 2014 US dollars.

Year	ICRISAT	Partners (BMGF)	Direct outputs	Intermediate outcomes	Discount factor 5%	US GDP Deflator
1999	4,728	4,728	5,673	3,782	2.08	74.0
2000	3,302	3,302	3,962	2,641	1.98	75.7
2001	3,228	3,228	3,873	2,582	1.89	77.5
2002	3,179	-	1,907	1,272	1.80	78.6
2003	3,117	-	1,870	1,247	1.71	80.2
2004	12,134	-	7,281	4,854	1.63	82.4
2005	12,933	-	7,760	5,173	1.55	85.1
2006	11,407	-	6,844	4,563	1.48	87.7
2007	11,112	-	6,667	4,445	1.41	90.0
2008	10,899	-	6,539	4,359	1.34	91.8
2009	27,039	38,936	39,585	26,390	1.28	92.5
2010	295,792	1,709,782	1,203,345	802,230	1.22	93.6
2011	290,095	1,676,850	1,180,167	786,778	1.16	95.4
2012	285,111	1,648,038	1,159,889	773,259	1.10	97.1
2013	280,858	1,623,457	1,142,589	761,726	1.05	98.6
2014	276,800	1,600,000	1,126,080	750,720	1.00	100.0
2015	-	1,969,500	1,181,700	787,800	0.95	102.0

Table 3. Total expenditure by VLS and VDSA partners in 2014 present value terms.

	Outputs (US$ million)	Intermediate outcomes (US$ million)	Total (US$ million)
Generation 1	14.7	12.4	27.1
Generation 2	7.7	5.1	12.8
Total	22.4	17.5	39.9

GDP deflator and then compounding forward at 5%. The expenditure in 2014 US dollars is presented in Table 2. The columns in this table can only be summed if a zero discount rate is assumed. The cost of establishing the VDSA databases and collection process, the VDSA outputs, was estimated to be US$7.7 million in 2014 PV terms and the cost incurred by the VDSA team in producing the intermediate outcomes was US$5.1 million, giving a total cost of the VDSA project in 2014 PV terms of US$12.8 million (Table 3). No attempt has been made to allocate the investment between the five intermediate outcomes.

Total expenditure across both projects in 2014 present value terms was US$39.9 million.

Note that no attempt has been made to date to attribute some share of ICRISAT overhead costs to VLS activities. If this were to be done, then again a distinction would have to be made between database assembly and intermediate outcome activities. Such overhead costs are rarely accounted for in impact assessment analyses presumably on the grounds that their opportunity costs are low.

There are two scenarios in which this total investment figure of US$39.9 million is useful. The first scenario is where we are able to value the total benefits from these intermediate outcomes that have accrued since the start of the VLS project and will continue to flow for many years to come. Note that real benefits before 2014 have to be compounded forward, as for costs, and future benefits discounted back to 2014 at 5%. However, for this estimate of benefits to be useful in a benefit cost sense, some estimate is required of the total investment by the non-VLS users of the VLS databases. The flow of total benefits must be related to the flow of total expenditures to give a meaningful measure of the rate of return on this investment.

A second scenario is where some share of total benefits is attributed to the VLS team. This estimate of benefits can then be related to the VLS investment of US$39.9 million to give a meaningful measure of the rate of return.

It is never going to be practical to estimate this total flow of benefits or the share of benefits to the VLS. It is more likely that the benefits and costs of particular intermediate outcomes will be estimated. Again attention has to be paid to relating a specific flow of benefits (additional to the flow of benefits in the 'without' project scenario) to the investments by the VLS/VDSA team and external users necessary to deliver this flow of benefits.

The benefits from the advanced rate of adoption of Maruti pigeonpea in Maharashtra arising from VLS activities is described below as an example of this type of analysis. In this example, the benefits from the intermediate activity funded by the VLS team and partners is not the total benefits of the yield gains from Maruti but the benefits obtained from advancing adoption of Maruti in Maharashtra by say three years. The costs of the activities required to achieve this faster adoption were estimated and related to the benefits of faster adoption but again the process of estimating these costs involved subjective attribution difficulties. An unresolved problem is how or whether to account for some share of the investment in the VLS database and infrastructure. There is no obvious rule of thumb that can be applied here.

By conducting evaluations of many of these intermediate outcomes – many because the share of benefits attributable to the VLS efforts is likely to be small – enough benefits attributable to VLS activities may be identified that will exceed the total investment of US$39.9 million. In my view, significant impacts of VLS activities have likely been through additions to the stock of scientific knowledge and human scientific capacity. Hence, investing in assessing the impact of accelerated technology adaption and accelerated rural policy development, especially for the VLS project, solely to quantify enough benefits to exceed this total investment figure is unlikely to be a wise use of resources. A share of impact assessment resources should be used for historical accountability but often a more valuable use of these resources is in guiding present or future research investments.

6 The VLS and VDSA Databases

Here, the scope of the databases and the data collection processes are explained. Then information about users and how they access the data are described. The section concludes with a discussion of the value of the databases.

6.1 The household level panel database

Much of the material in this section has been supplied by the VDSA team and has been lightly edited. The household level panel database comprises household-level survey data collected from: (a) the six original VLS villages in the Indian SAT for the period 1975 to 1984 and 1989; (b) the original six villages for the period 2001–2008; and (c) from 42 villages (including the original six villages) in India and Bangladesh for the period 2009 onwards, which was funded by the Bill & Melinda Gates Foundation. Data up to 2014/15 have been released through the VDSA website.

The household data were collected by ICRISAT's resident field investigators who lived in the villages and periodically revisited the same households during the year. The data were collected through the following modules:

1. Household Census Schedule (VLS-A) for information on family size, land holding details and sources of income
2. Household Member Schedule (VLS-C) for all information about the family members like their age, sex, relationship with head, education, occupation, and information about any attached laborers.
3. Plot and cropping pattern schedule (VLS-D) for all information about the individual plots such as area, irrigated area, ownership status, source of irrigation, value, revenue and cropping pattern.
4. General Endowment Schedule (GES) for information on resource endowments (family composition, land, livestock, farm implements, residential building, consumer durables, stock inventory, debt and credit) of the household; role of gender in ownership and decision making; coping mechanisms adopted by the household during drought years. This module is collected once in a year in the month of July.
5. Monthly Price Schedule (VLS-M) for information on average prices of selected commodities and services for the previous month as recalled by different persons.
6. Household Transaction Schedule (VLS-L), which gives details on consumption quantities and expenditures, income by source, production expenditure, changes in the credit and debt position, capital gains and losses, etc.
7. Labor, Draft Animal and Major Machinery Utilization Schedule (VLS-K), which records how the family uses the resources under its control such as the labor of family members and servants, owned bullocks, owned tractors and power tillers.
8. Cultivation Schedule (VLS-Y), which records operations and their costs in input-output form for each plot held by the household. It also includes the important characteristics of each plot and sub plot such as soil type, ownership, irrigation status, land value and revenue;
9. Livestock Economics Schedule (VDSA–Z), which gives information about the maintenance of livestock and small ruminants owned by the household and total expenditure and returns from livestock rearing during the survey year. Information about the purchase of fodder and feeds is also recorded.

After interviewing the respondents on a particular day, the resident field investigator checks and finalizes the entries made in the interview schedule. Then the data are checked by field supervisors to ensure consistency and accuracy before they are entered into the electronic form using CSPro software following the double entry method. Data are then validated through tools available in CSPro to identify and remove entry errors before being exported to Excel and released through the VDSA website (Figure 4).

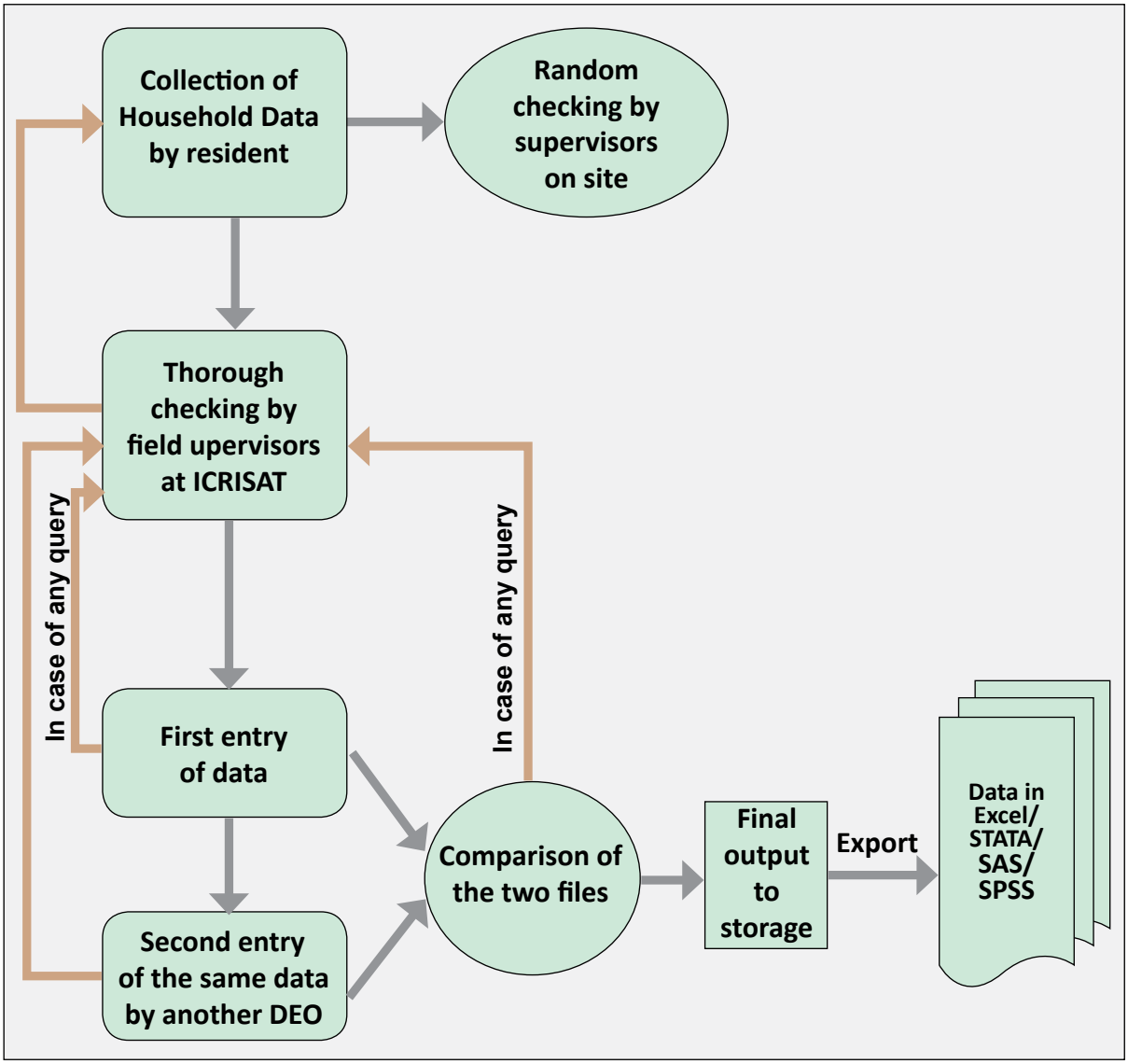

Figure 4. Process of data collection and entry.

The VDSA Project is also pioneering the Computer Assisted Personal Interviewing (CAPI) method of data collection. In Bangladesh, the project has trained more than 50 researchers on CAPI method of data collection. Now, other CGIAR centers such as CIMMYT and World Fish have learned this method and have started using it in Bangladesh.

6.2 The meso-level database on South Asian agriculture

The meso-level dataset contains data pertaining to the performance, structure and behavior of economies at a disaggregated district, state, or province level in India (1966 to 2010) and Bangladesh (1952 to 2012). Sub-district (taluka) level data in India, for districts in the SAT region and eastern India where the VLS villages are located have also been collected. Key variables include data on area, production and yield of all crops, rainfall, irrigated area by crop, prices of agricultural commodities and inputs, gender disaggregated agricultural wage rates, farm harvest prices, fertilizer use, livestock production (milk, meat and eggs), operational holdings, inflation, land utilization, cropping intensity, agricultural credit, roads and markets, and human capital (rural literacy) and poverty. Other variables include data on labor force and employment of workers, schedule caste and schedule tribe population, temperature, soft infrastructure (banks, post offices, hospitals, educational institutions, etc.), veterinary institutions, gross/ net domestic products and per capita GDP, value of output, and climate.

The VDSA has added value to the district level data collected from the government agencies in India and Bangladesh through digitization and harmonization of data format across years, incorporation of time series compatible district datasets; Agro-ecosystems and production systems; Rain-fed/ irrigated; SAT/ Non-SAT; Regions-within state; Population census code linking the GIS. District level datasets provide a comprehensive repository for data that identify relevant regions/districts for targeted poverty alleviation development initiatives. Meso-databases act as links between country-level macro data and household-level micro data. Its consistent collection processes and level of detail serve as a powerful research tool for priority setting and in tracking inter-district and intra-district economic changes. The dataset is invaluable in policy simulation and development and providing feedback to researchers by analyzing the meso-level data corroborated with micro-level evidence regarding the situation of vulnerable sections of society.

6.3 Access to the databases

An information portal (http://vdsa.icrisat.ac.in) is used for disseminating this rich resource to the global community. The website gives access to information about the VDSA project and research reports prepared from analysis of the data. Users across the globe can get access to ICRISAT's legacy data from 1975 to 2008, VDSA data from 2009 onwards including that from eastern India and Bangladesh. Access to the data is free.

The VDSA project has developed the VDSA Knowledge Bank with user-friendly data retrieval and on-line analytical processing features that were not available at the portal described above. It is the first of its kind in the CGIAR system and also the first in the world for the management of rural household survey data. It is the single repository of all data, including household survey data, collected by ICRISAT since 1975 from the original six VLS villages in Telengana and Maharashtra, along with new data collected through the VDSA project from 42 villages in India and Bangladesh (from 2009 onwards). The Knowledge Bank has greatly facilitated the harmonization of the farm household data collected at different periods with different modules/objectives. With this new innovation, web-based dissemination of data is more efficient both for ICRISAT and those who use the data. The VDSA Knowledge Bank can be accessed through the VDSA website and also directly from the URL at http://220.227.250.220/.

Features of the VDSA Knowledge Bank include:

- A total of 17 Summary Reports (pre-defined) on key indicators of rural economy such as household income by source and class, consumption and expenditure on food and non-food items, asset ownership and value, distribution of land ownership, rainfall
- A total of 42 user-defined reports on various aspects of household economy, investment, government development programs, stock inventory, farmer's behavior and coping mechanisms, profitability of crop and livestock farming, employment, prices of essential commodities and agricultural inputs.
- Raw data access for direct download
- Project management features will assist in enhancing performance and service delivery and tracking user details and usage statistics, and popular data downloads
- RSS feeds inform users about new data availability and latest developments, promoting use of the VDSA Data Warehouse
- Survey Instruments include all the questionnaires for different regions and different years

6.4 Use of the databases

VDSA databases have been used by scholars in India and other countries for research in development economics, dynamics of rural economies and farming systems. As of January 2015, 792 unique users from 39 countries of Asia, Africa, Europe and North America have downloaded the data since

December 2011. These include 366 students including 212 PhD students from about 150 universities/ institutes around the world. Use of the VDSA datasets by Asian students and researchers has increased rapidly in recent years. As of January 2015, 426 researchers from India download the data on a regular basis.

Out of the 366 student users, 101 students have provided specific information about the issues they will investigate using the VDSA databases. Areas of study include natural resource management (18 students), production economics (16), labor market (14), rural credit (10), risk and uncertainty and insurance (9), development studies (7), gender (7), nutrition (7), farm management (6), poverty, income and wealth (5), research management (1), and welfare economics (1).

Out of the 426 researchers, 120 researchers have specified their research interests. These include production economics (27 researchers), natural resource management (23), development studies (14), nutrition (12), poverty, income and wealth (9), risk and uncertainty and insurance (8), farm management (7), gender (5), labor market (6), welfare economics (5), econometric analysis of efficiency in production (2), rural credit (1), and common property resources (1).

The VDSA databases are important sources for policy analysis at the CGIAR, Advanced Research Institutes (ARIs) and national research programs. The demand and usage of district level data for India and Bangladesh has been expanding rapidly with regular requests from Indian Council of Agricultural Research (ICAR), World Bank, World Food Program, ICDDRB; lead research institutes and universities in India (CESS, NCAP, ISEC, etc.) and Bangladesh (BAU, BRRI, BARC, BARI, BSMARU, etc.); ICRISAT; IRRI; CGIAR Research Programs (CRPs) on Policies, Institutions and Markets; Grain Legumes; Dryland Cereals; other CRPs and CGIAR institutes (CIMMYT, WorldFish).

Davis et al. (2015) reported a survey of 390 people registered with the VDSA databank in December 2013. Seventy-eight responded to the survey from 18 countries, over half from India. Almost 90% of the respondents had downloaded VDSA data, 60% reported using the data, and another 26% were still evaluating the usefulness of the data to them. Twelve respondents reported that they had 15 journal papers at some point in the publication pipeline. Many of the survey respondents have visited ICRISAT and VLS villages and formed some ongoing relationship with VDSA staff. The increase in the number of users from 390 in December 2013 to 792 in January 2015 is noteworthy.

6.5 The value of the VDSA databases

As already discussed, these datasets have the characteristics of global public goods. The annual cross section and time series nature of the data enabled not just trends in key measures of welfare to be observed but allowed the behavior of households in response to weather and market uncertainties to be analyzed in a way that is not possible with intermittent data (Walker and Ryan 1990, p.10). The analyses allowed by the VLS panel data and their findings across the five intermediate outcomes are described in following sections. Not only did the datasets allow this type of analysis for the first time but it stimulated the development of new econometric techniques designed to analyze panel data that have had many applications far removed from the VLS project.

When thinking about the value of the databases, it is important to consider ‘without’ scenarios. One scenario might be that the VLS project made panel data available several years or perhaps decades earlier than would otherwise have been the case. In Section 9, the intermediate outcomes in the form of new methods and theories are discussed. As evidenced by the high rate of citations to this body of scientific papers, much of this research was path-breaking. It was made possible by the unique VLS dataset with its time series and cross-section dimensions. Unfortunately, I did not formally enquire about when comparable datasets became available around the world. Knowing this would have provided some guidance as the number of years by which the VLS project advanced the availability of the intermediate outcomes identified here. However, I have become aware of other datasets being assembled in India and Africa.

In India, the National Council of Applied Economic Research (NCAER) conducts the Additional Rural Incomes Survey (ARIS) to supplement economy wide surveys. The survey started in 1971 and was repeated in 1982, 1999 and 2006. The survey covers all states with 9,500 households in the sample in 2006. In Africa (and elsewhere), the World Bank sponsors with funding from the Bill & Melinda Gates Foundation, the Living Standards Measurement Study (LSMS) and within that, the Integrated Surveys on Agriculture (ISA). The data collected seem comprehensive but as yet there are few years in this survey. Therefore, while these competitors allow a tracking of key measures of welfare, they are not as timely as the VDSA databases, and they do not allow analyses that explain the influence of weather and market uncertainty on household choices.

The NCAER and the LSMS databases are competitors with the VDSA databases but they are likely to be imperfect competitors because their panel datasets are shorter in length, as noted above, and not as comprehensive in respect of important household as distinct from farm variables like off-farm income, household assets and liabilities, and gender and nutrition dimensions. The unique features of the VDSA databank and its forerunner in the VLS databank mean that these databanks still enable analyses of the behavior of farm households with respect to price and weather risk that cannot be undertaken by the competitors.

7 Special purpose surveys

The second direct output of the VLS/VDSA projects was an infrastructure for farming systems research, community development projects and special purpose surveys. How this infrastructure was used to assist in farming systems research and in community development projects is discussed more fully below. Here, the attention is on the numerous special purpose surveys conducted in the VLS/ VDSA villages to support specific lines of enquiry.

Table 4 (supplied by project staff) lists 24 special purpose surveys undertaken in the VLS/VDSA villages between 1975 and 2014. I have not had the time in this project to review all the surveys; however it is most likely that these surveys, making use of the VLS/VDSA infrastructure, have been cost effective. Moreover, having access to the baseline VLS/VDSA data enriches the analysis of survey data and helps control for observed effects in the year of a survey, which may be 'seasonal' in some dimension. As can be seen from Table 4, many of these special surveys have been published.

In 2013–2014, a large research program into nutrition and gender issues was commenced in eight VLS villages[4]. This study derives benefits from its complementarities with the VDSA project. Nutrition data for individuals rather than families, disaggregated by both gender and generation (age) are rarely collected alongside large-scale, cross-sectional and longitudinal agricultural data sets. The understanding of how agricultural changes or interventions affect nutrition status has, therefore, largely remained a mystery.

The VLS/VDSA databases are among the few in collecting nutritional data alongside agricultural data in selected sites of India from 1975 to the present (including surveys in 1977 and 1992–94). The contribution of the projects to the global understanding of household decision behavior under risk and uncertainty, and in monitoring changes in household welfare and poverty dynamics has been mentioned. Additionally, the VLS project was path-breaking in collecting data that allowed for analysis by gender of issues such as labor participation, effect of mechanization, changes in education over time, wages, government development programs and their benefits, and memberships in groups (formal and informal). Ryan et al. (1985) reported a study of diets and nutritional status in the VLS villages.

Building on these original datasets, the 2013–2014 Nutrition and Gender project will allow an examination of changes over time in key gender-related and health, nutrition and institutional-related issues giving a better understanding of the links between agriculture and nutrition. This data is being collected in special purpose surveys of 487 households in 8 VLS villages in three states (Telangana, Andhra Pradesh and Maharashtra) of SAT India alongside the regular VLS data collection. Women field investigators were hired and trained to collect 24-hour dietary recall data from both men and women. Time allocation and social network data were collected by both male and female enumerators from men and women, respectively. The existing male resident field investigators in the VDSA SAT villages assisted the women investigators. Planned analyses include:

- What are the factors associated with nutritional status of men, women and children. If possible, can we find which factors contribute to the achievement and changes in nutritional status of the target groups (men, women and children) ie., can causality be established
- Analyzing the changes in labor participation of men and women in agriculture, consumption patterns and expenditure, nutritional status of men, women and children at different points of time - 1975; 1992–93 and 2013 taking into account the changes in the external environment – e.g., cropping pattern changes; diversification of income and livelihood sources, impact of government programs (FS bill), knowledge and information access, climate variability, human capital enhancement, access to and control over assets.
- Metrics to calculate the empowerment index and/or use the existing WEAI index developed by USAID to understand and document empowerment of women in relation to men in different production systems

4. Much of this material was provided by Dr R Padmaja and her team

Table 4. Special purpose surveys conducted from 1975-77 to 2014.

Topic	Year	Households	Reference
Household time allocation	1975–77	Respondents	JG Ryan
Price information	1975–78, 1980–85	Key informants	MV Oppen
Nutrition and health	1976–78	Respondents	PD Bidinger
Tenancy	1976–78	Respondents	NS Jodha
Risk attitudes	1977	Respondents	HP Binswanger
Fertilizer use history	1977–78	Respondents	D Jha
Labor relations	1979–80	Key informants and respondents	VS Doherty
Well ownership and group action	1979–80	Respondents	VS Doherty
Social relations	1981–82	Respondents	VS Doherty
Price and yield expectations (from Dokur and two nearby villages)	1982–83	30 well owners	TS Walker
Evolution of common property resources	1984	Key informants	NS Jodha
Retrospective family history	1984–85	Respondents	World Bank study
Benefits and cost of land fragmentation	1985	Respondents	V Ballabh
Pesticide use history	1985	Respondents	CS Pawar
Alternative indicators (nutrition) study	1992–93	80 HHs; old VLS HHs (with split-off families) and non-VLS HHs	Kim Chung (ICRISAT-IFPRI study)
Social capital and migration: A study of development pathways in Dokur Village	2004	VLS and non-VLS respondents	BVJ Gandhi
Linkages and social networks and development programs	2005–06	Respondents	Pramila Krishnan
Household tracking and household linkages (migration)	2005–06	Original VLS HHs (including split-offs)	Stefan Dercon / Reena Badiani
Four-monthly health and shocks survey	2005–07	Respondents	Stefan Dercon
Migration, labor, trade, and income generation	2006	Respondents	Stefan Dercon
Livelihood insecurities in the semi-arid tropics of rural Andhra Pradesh; Focus on migration and HIV AIDS	2006–07	VLS and non-VLS sample	BVJ Gandhi
Study on addressing extreme poverty in low-income countries: Risk and shocks	2007	VLS and non-VLS sample	BVJ Gandhi
Social networks and relationship	2008–09	VLS and non-VLS Sample	R Padmaja / MCS Bantilan
Women's empowerment and nutrition in the Semi-Arid Tropics (gender and nutrition)	2013–2014	VLS and non-VLS sample	R Padmaja

- Test the assumption that calorie intakes and requirements of rural men and women have declined due to lower levels of physical activity associated with mechanization of agriculture and change in lifestyle (24 hour dietary recall plus 24 hour time allocation)
- What are the trends in food and nutrient consumption and expenditures of individuals (men, women and children), and at the household level over time (1975–2012)?
- What is the relationship between women's socioeconomic status and their ability to influence household decisions and intra-household allocations of food, health, and care?
- Understanding the links between women's income, asset ownership and nutritional status of children and the household.
- Mapping the social network architecture of rural communities and analysis of the different institutions that contribute to empowerment or (disempowerment) of the rural poor and how these links and associations help in information and knowledge flow and spread
- Adding some nutrition variables to the VDSA meso-level data to gain new insights into India's population and state-level nutrition patterns alongside production trends.

Special purpose surveys have also been conducted in Bangladesh and have been facilitated by VDSA village infrastructure including:

- A study of hybrid rice found that poor grain eating quality, lower market price, high production cost, and short keeping quality of cooked rice were major obstacles for the expansion of hybrid rice in Bangladesh. Now, IRRI and private companies are giving priority to these problems.
- A study about gender impact of agricultural diversification found that shifting from rice to fish farming increased overall household income but employment for women was reduced and income is controlled by men. Their position can be improved with better access to credit, and information about improved farming technologies.
- A study about groundwater irrigation in Bangladesh, which showed that the water market has encouraged efficient water use in rice and reduced the depletion of groundwater resources.

8 Capacity Building through Training (C_t)

Gordon and Chadwick (2007, p.15) described capacity building as building human capital in the form of 'the understanding, skills and knowledge base of individuals and institutions'. They pointed out that 'evaluation of capacity-building generally stops at assessing the capacity built (such as skills gained) and only occasionally goes on to measure capacity utilized'. Since human capital is used jointly in research with other inputs such as machinery, chemicals, labor etc., it is difficult to identify and measure the contribution of capacity building (an attribution problem). Gordon and Chadwick (2007) defined human capital as 'the understanding, skills and stock of knowledge applicable to the particular environments of the workers and decision-makers (p.15)' and capacity building as 'encompassing training and all other forms of learning that enhance the knowledge, understanding and competencies (skills) of individuals (p.18)'. They distinguished human capital from the stock of knowledge from research activities arguing that the potential impact of human capital is potentially larger because it is better able to influence the institutional environment in which research is undertaken.

As we have seen, the VLS/VDSA projects invest in activities across a spectrum including pure and applied research, policy research and development, extension and human capacity building in pursuit of economic, social and environmental benefits. Capacity development has been a major component of all the activities of the VLS/VDSA team and its partners whether through formal training or informally as 'learning by doing' during research projects. In terms of the model in Section 3, capacity building activities can be thought of as adding to the stock of human scientific capacity, C. If useful, it can be eventually applied in the development of new technologies, K, or farm policies, J, that enhance the welfare of rural households. The lag between capacity building and welfare impacts can be long. This contributes to the difficulties in valuing capacity building.

It is difficult to separately identify and estimate the economic impact of investment in formal or informal capacity as distinct from other research activities. The main reason for this has been the jointness between these different types of investment such that there is no theoretically sound way of decomposing investment into capacity building and research components. Typically, a 'research' project also increases human capacity and scientific knowledge through 'learning by doing' as well as developing a technology to be applied on-farm. Similarly, formal training programs are likely to add to scientific knowledge and the stock of farm technologies as well as the more obvious addition to human capacity. Data on research investment typically makes no attempt to separately identify investment in capacity building because of these conceptual difficulties.

Additionally, the 'spillover' benefits of capacity building to later R&D activities have at best been identified qualitatively. Ignoring these 'spillover' benefits means that unless they are reflected in subsequent impact assessments, the economic gains from R&D activities are likely to be understated. Even econometric studies of returns to agricultural R&D at a sector level understate economic gains because the future flows of benefits from capacity building are not captured in historical measures of productivity.

While acknowledging the importance of 'learning by doing' in the whole range of VLS/VDSA activities, here, we focus on the impact of formal training provided through the projects. Davis et al. (2015) conducted a tracer study of those who have undertaken training through the projects. Given the difficulties, no attempt has been made to value the capacity built. Rather, the contribution of the work of Davis et al. (2015) has been to more clearly identify how capacity built through training has been utilized in subsequent research and extension or policy development work.

The VDSA Project is significantly contributing to capacity development in Bangladesh. The project provided research grants to one Ph.D. student and one M.S. student. It has trained more than 100 Bangladeshi researchers on social sciences research methodologies including data collection and analysis.

The training through the use of VLS/VDSA data of post graduate students around the world (external to ICRISAT) is discussed in Section 9.

8.1 Benefits from training identified by the VLS learner – participants

A key component of the efforts to identify the capacity building outcomes from training opportunities provided by the VLS program has been the 'tracer study' of the 211 'learner participants', LPs, who have experienced training in the VLS Program by Davis et al. (2015). By design, 'tracer' studies do not provide a quantitative estimate of the value of human capacity building. Nevertheless, given the subjective nature of alternative quantitative approaches, well-designed 'tracer' studies of individuals and the institutions where they work have the potential to identify strong causal pathways between training and efficiency gains for at least a sample of individuals, which lend support to the findings of more quantitative studies. The tracer studies might be useful in identifying case studies for more intensive quantitative analysis.

Tracer studies have evolved from studies where the focus is on asking the respondents about their training experience (to guide improvements in training), to studies where skills acquired were identified. In general, the responses sought have been subjective in nature. More helpful would be studies requiring respondents to identify specific skills and provide more objective evidence of how these skills have been applied both personally and institutionally. Studies by Kumar and Nacht (1990) and EDG (2006) have attempted this.

In the study by Davis et al. (2015), strong emphasis was given not only to describing the capacity built during training but also to identifying how that capacity has been used in the participants' later careers. Respondents were asked to identify more analytically, the changes in outcomes for them personally for their institutions and/or for their research program during or soon after their time in the VLS program that could be directly and substantially linked to their VLS training experience. Davis et al. (2015) intended that this approach provide a conservative evidence based assessment of the significance of VLS training activities.

Within this context, the questionnaire was designed to follow the structure of a strong impact pathway narrative and provide opportunities for respondents to provide specific details of changes attributable to VLS training. In general terms it had the following key components (adapted from Gordon and Chadwick 2008, p.106):

- What capacity were respondents expecting to build – why did they come to ICRISAT
- Defining capacity built;
- Defining how this capacity was utilized;
- Identifying personal outcomes – promotion, higher income, satisfaction;
- Identifying institution outcomes;
- Identifying research program outcomes.

Only 10 of the 211 LPs spent 2 weeks or less at ICRISAT. Just over 100 spent between 2 weeks and 2 months and the rest spent up to 6 months at ICRISAT. There were 39 respondents to the survey. The major areas where they sought training were:

- Institutions and markets (39%);
- Village dynamics (23%);
- Nutrition and health (23%);
- Risk and vulnerability (19%);
- Policy studies (19%).

About ¾ of the respondents said that their training was relevant to themselves and their institutions and about ¾ agreed that they had an increased capacity for research. Almost half the respondents said that their VLS training helped them gain employment within 3 years of training, and most of them said that their training helped in their promotion during this time. Beyond three years, as expected, the contribution of the VLS to employment and promotion is more difficult to discern.

About 40% said that in the first three years, they were able to provide training and influence the direction of research in their institution partly as a result of their VLS experience. Many of those trained now work in positions where they are likely to be influential. Not all respondents identified their present positions but there was 1 national minister of agriculture, 18 professors, 2 World Bank economists, 4 senior managers, several in agricultural research institutions and 4 PhD students. Given their positions, the subjective statements above about the contribution of the VLS training seem credible.

Davis et al. (2015) found that 16 of the respondents, among which 9 were PhD scholars during their ICRISAT association, indicated that they had written 24 articles, using the VLS related resources, and many of them were published in high-impact journals with numerous citations. Other publications included two books, one MPhil thesis, one seminar proceedings, a book chapter and two project reports. If this rate of publication applied to the non-respondents as well then it is likely that the VLS/ VDSA LPs have published at a rate similar to those completing PhDs.

These views, while highly supportive of the impact of the VLS training, are nevertheless subjective. Davis et al. (2015) were unable to elicit responses to that part of their questionnaire seeking specific examples of how respondents applied their training. It is likely that poor question design was partly responsible. Further experimentation in later tracer studies is required in eliciting this type of more objective, if somewhat anecdotal, evidence of the impact of formal training.

9 New Methods and Theories (L_t)

The cross section (household) time series nature of the VLS/VDSA data make these data extremely valuable for testing important economic theories about the behavior of households through time. Testing these theories using panel data has required refining methodologies that allow household and time series effects to be separately identified. Conceptually, activities of this nature add directly to the stock of human scientific capacity, C, in the form of new knowledge and techniques available for use by economists (and others), which are later reflected in changes in output through changes in K, the stock of technologies available to farmers or J, the stock of knowledge available to farm policy makers (as described in Section 3 above).

The impact of the databases on development thinking is well known. In a thirty-year, retrospective comparison of the changes in living standards in the six VLS villages, Stefan Dercon of Oxford University and his co-authors sum up that impact as follows:

'It is hard to think of any other data set in development economics that has been as influential as the village level data collected between 1975 and 1984 ... Even though only 240 households were covered by the core data set...some of the most influential articles in empirical development used this data set, on themes such as nutrition, technology adoption, tenancy contracts, activity choice, consumption smoothing or risk sharing. Many stylized facts about the microeconomics of development appear to stem from these villages. Take a random published empirical paper dealing with the microeconomics of development written between 1985 and the mid-1990s and the odds are that it will be a paper on these six villages (Badiani et al. 2007, p.1).'

As with capacity building through training, there are no commonly applied techniques to value the economic impact of additions to the stock of scientific knowledge in the form of advances in theory and methodology and their applications, as reported in theses, books and scientific publications. The VLS/VDSA team has attempted to keep a record of all publications and theses that have directly used the databases but this is likely to be incomplete because most publications have been written by people external to ICRISAT who have no requirement to report back. Then there are all the papers that are 'derivatives' of those who used the data directly. Tracing all the outputs associated with the VLS/VDSA databases is a difficult task and consequently describing outcomes and impacts even qualitatively will necessarily be incomplete.

VDSA sources (Publi_List_New_011274.xls) record a total of 614 publications of all types and 53 Masters and PhD theses from the VLS and VDSA projects. Here, the focus has been narrowed to refereed journal papers and PhD theses. No doubt some conference papers and other reports have been highly influential but these are difficult to identify.

In the next subsection, the number of journal papers and citations is reported. The journal papers have been classified into 14 research areas to identify those areas with most effort and success in using the databases. Similar information is presented for the PhD theses based on VLS/VDSA data.

In the following subsections, the contributions by the databases to some of the key research areas are reviewed:

- Analysis of risk and uncertainty
- Analysis of common property issues
- Efficiency analysis
- Production economics
- Nutrition and gender economics

This has been done by reviewing some of the most often cited papers in these areas. There has not been time to review all the "VLS" papers in these research areas nor is it appropriate to judge the significance of the selected papers in all these research areas, especially those in which I have had little professional experience. Because the papers reviewed are all highly cited, it is highly

probable that they have been influential in their fields. I have reviewed these papers largely for the extent to which they rely on the panel data nature of the VLS/VDSA databases which is their unique characteristic.

9.1 List of refereed journal papers and PhD theses

Using Google Scholar, the VDSA team identified 290 papers containing the key words 'ICRISAT+village level stud*' and which had been cited elsewhere at least once. The total number of citations to this set of papers was 34,420 until 28 October 2014. The team identified a set of 15 papers that have been cited almost 18,000 times (Table 5). Five of the papers have been cited more than a 1,000 times.

Table 5. Fifteen most cited papers that have used ICRISAT VLS data series, or acknowledged ICRISAT VLS data sources in the document.

Battese GE and Coelli TJ. 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics.* Vol. 20: pp. 325-332. **(3,947)**

Battese GE and Coelli TJ. 1992. Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis*. Volume 3, Issue 1-2, pp 153-169. **(2,210)**

Townsend RM. 1994.Risk and insurance in village India.*Econometrica,* Vol.62, No.3, pp.539-591. (**1,858**)

Binswanger HP. 1980. Attitudes toward risk: Experimental measurement in rural India. *American Journal of Agricultural Economic*s. Vol. 62, No. 3, pp 396-407. **(1,229)**

MurdochJ. 1995. Income smoothing and consumption smoothing.*The Journal of Economic Perspectives*. Vol.9.No.3. pp103-114.**(1,096)**

Rosen Zweig MR and Binswanger HP. 1992.Wealth, weather risk, and the composition and profitability of agricultural investments.*The Economic Journal*Vol. 103, No. 416. pp. 56-78. **(888)**

Udry C. 1996. Gender, agricultural production, and the theory of the household.*Journal of Political Economy*. Vol. 104, No. 5.pp 1010-1046. **(800)**

Rosen Zweig MR and Stark O.1989. Consumption smoothing, migration, and marriage: Evidence from rural India. *The Journal of Political Economy*, Vol. 97, No. 4. pp. 905-926. **(786)**

Hanan G. Jacoby and Skoufias E.1997.Risk, financial markets, and human capital in a developing country.*The Review of Economic Studies*, Vol. 64, No. 3. pp. 311-335. **(778)**

Jodha NS. 1986. Common property resources and rural poor in dry regions of India. *Economic and Political Weekly*, Vol. 21, No. 27. pp. 1169-1181. **(753)**

Bauer PW. 1990. Recent developments in the econometric estimation of frontiers. *Journal of Econometrics*, Volume 46, Issues 1–2. Pages 39–56.**(742)**

DerconS. 2002. Income risk, coping strategies, and safety nets. Background paper *World Development Report* 2000/01. **(704)**

Walker TS and Ryan JG. 1990. *Village and household economics in India's semi-arid tropics*. **(651)**

Rosen ZweigMR. 1988. Risk, implicit contracts and the family in rural areas of low-income countries. *The Economic Journal*, Vol. 98, No. 393, pp. 1148-1170. **(595)**

Battese GE and Coelli TJ. 1993. A stochastic frontier production function incorporating a model for technical inefficiency effects. Working paper, Department of Econometrics, University of New England, Armidale.NSW.**(590)**

It seems likely that some of these papers, for example the paper by Murdoch (1995), are review papers referring to other papers that were directly based on an analysis of the VLS/VDSA data. Hence, from VDSA sources, only 143 journal papers were identified. It is likely that these papers are based on analyses of the databases. The set of 143 papers is a subset of the papers identified from Google Scholar, and these papers have been cited almost 30,000 times. Note that by focusing on journal papers, highly cited other forms of publication like the working paper by Battese and Coelli (1993), the last of the 15 most cited papers, have not been included, although the number is likely to be small.

The 143 research papers (listed in Appendix 3) have been classified into 14 research areas. These areas, the numbers of papers in each area, and the numbers of citations to these papers are detailed in Table 6. The research areas of risk and uncertainty, production economics and efficiency analysis account for over 20,000 of the citations. This high rate of citations likely arises because these papers were early users of the unique time series and cross-section nature of the databases.

Table 6. Classification of VLS/VDSA journal papers by research area.

Subject Area	No. of Papers	Citations
Farm management, farm level budgeting exercises	15	596
Production economics	27	3084
Econometric analyses of efficiency in production	7	8112
Risk and uncertainty and insurance	30	11383
Rural credit	9	1459
Labor market	14	804
Land market	4	147
Natural resources	0	0
Common property resources	3	1127
Poverty, income, wealth	14	1275
Trade or market level demand and supply	1	0
Nutrition	4	535
Gender	8	526
Research management	7	126
Total	**143**	**29174**

Only 15 of these papers have been published since 2000 when the VDSA project started. It is also noticeable that only 17 papers were published before 1984 when the VLS project was halted. As with all forms of research, there are long lags. Most of the papers using the VLS data were published in the 90s. Hence, we can expect an upsurge in publications using the VDSA data in the coming years. A weakness of this assessment is that I did not enquire about the areas of research to which current users were applying the VDSA data. However Davis et al. found that within their sample of 79 VDSA registrants, there are at least 15 scientific papers from 12 researchers that are in various stages of publication. The VDSA team needs to promote the VDSA databases and provide assistance to users to ensure a continuing demand for the databases and hence, a continuing flow of benefits from the VDSA investments.

I can't value the contribution of this body of research to the stock of scientific knowledge but the large number of citations suggests that the unique panel data characteristics in particular, have allowed research, which has been highly influential across a range of research areas.

According to VLS/VDSA sources, 53 people have used VLS data as the basis of their analyses in their PhD and Masters dissertations (Appendix Table 3). Thirty-eight people have used the data as the basis of their PhDs. The distribution of PhDs across the 14 research areas is detailed in Table 7 and the PhDs are listed in Appendix 15.4. Production economics is the research area where the largest number of PhDs was undertaken.

Table 7. PhD Thesis by sub-category, and by number of citations.

Subject Area	No of Papers	Citations
Farm management	3	17
Production economics	16	121
Efficiency analysis	2	0
Land economics	1	0
Risk and uncertainty and insurance	4	18
Rural labor	6	18
Rural land	1	3
Sociology	1	1
Poverty, income, wealth	1	0
Nutrition	3	6
Total	**38**	**183**

9.2 Analysis of risk and uncertainty

The research into the attitudes of SAT farm families to risk by Binswanger-Mkhize and colleagues has likely had major impacts both in terms of its contribution to the stock of scientific knowledge and its implications for both rural policy and research priorities. Prior to this research, most empirical studies of risk aversion were based on small samples and hypothetical choices with small payoffs administered by interviewers. Binswanger-Mkhize (1980) presented 330 farm families with real payoff choices in his approach to eliciting empirical estimates of risk aversion.

The original paper by Binswanger-Mkhize (1980) has been cited 1229 times according to Google Scholar. It is highly likely that modern experimental economics, which also uses real payoffs, owes some debt to Binswanger-Mkhize's original work although I have not yet established this.

The findings of this body of research were that 'when payoffs are fairly high, farmers typically are moderately risk averse, with very few farmers being extremely risk averse and none being risk preferring' (Binswanger-Mkhize 2013, p.63) irrespective of size and other differences between farmers. In related research by Pender (1996), farm families were found to have very high discount rates and faced extreme liquidity and credit constraints.

These understandings about the attitudes for farm families to risk and their rates of time preference are likely to have influenced the direction of research at ICRISAT and farm policy more generally by governments in India and elsewhere. Research priority setting (Section 10) and rural policy development (Section 11) are discussed in more detail later but the contribution to these areas of the VLS based risk and uncertainty research is briefly mentioned here.

According to Ryan (1984), prior to the work by Binswanger-Mkhize and colleagues with the VLS farm families, research priorities were often based on the conservative safety first principle to account for risk aversion by small farmers. The implications of the findings of Binswanger-Mkhize relate closely to the findings of Ryan and Rathore (1980) regarding farm size and technology choice presented earlier. To quote Binswanger-Mkhize (1980, p.406):

'….. differences in investment behavior observed among farmers facing similar technologies and risks cannot be explained primarily by difference in their attitudes but would have to be explained by differences in their constraint sets, such as access to credit, marketing extension, etc.'

These constraints were more likely to limit input use and technology adoption than risk aversion. Ryan (1984) argued that these findings about risk explained the reluctance of farmers to adopt new technologies, especially when the standard deviation of outcomes is more than twice the average increase in returns. Binswanger-Mkhize (2013) argued that these findings from the VLS villages about the heavy burden on poor families from weather risk was one factor influencing the direction of ICRISAT research towards breeding crops more tolerant of difficult conditions.

The major contribution from a lot of studies is the profound implications of covariance of risk on everything in rural areas, including social protection. The finding that households are able to self-insure against idiosyncratic risks but not systemic or covariant risk means that much of social protection should focus on insuring against covariant risk[5].They found that the burdens on poor families from major weather and price disturbances are too onerous for the usual informal risk diffusion mechanisms operating at a village level (especially with the decreasing availability of common property resources) and generally meant that poor farmers made suboptimal use of inputs and capital items. Moreover covariant risk and moral hazard makes it difficult to devise viable insurance mechanisms and rural credit facilities.

9.3 Analysis of common property resources

One of the important components of the VLS since its inception has been "recording and understanding the overall village situations" including the commonly held resources in the village.

These insights complimented the analysis of farming systems based on private lands by introducing the contextual factors. This was later formalized through institution of a comprehensive study of common property resources, CPRs, between 1982 and 1986 funded by the Ford Foundation in 82 villages in dry regions of India including 10 VLS villages in two states. The methodology included household survey using stratified random sampling of households based on the category of landholdings[6].

The research effort was led by Dr N Jodha who was part of the VLS team. As noted in the previous section, Jodha's papers have been widely cited. Dr Jodha has held key positions in different commons related research programs and associations such as the IASC and South Asian Network for Development and Environmental Economics (SANDEE) and at the World Bank.

The results of the first comprehensive study of CPRs in India identified their importance to livelihoods from income contributions and the smoothing of consumption, especially for the poorer households. The study noted the decline in their area and productivity over time, highlighting several reasons for the decline. Ryan (1984, p128) noted that Jodha (1986, cited 753 times) had found that common property resources contributed significantly to the income and nutrition of lower income groups in the VLS villages.

Access to household panel data enabled the strong role played by the CPRs to be established through observing seasonal variations in the consumption of fodder, fuel and other products from CPRs across sample households. Further, it was found that CPR based activities, including collection and processing of products from CPRs formed a significant share of households' employment, especially the poor for whom it was marginally higher than their employment on their own farms. VLS data indicated that income from CPRs helps reduce rural inequalities.

The results of this first comprehensive study led to the emergence of the new research and policy issue of "common property resources" in India. Soon, many CPR studies emerged in different locations/countries supported by different agencies (World Bank, International Association for the Study of Commons (IASC), FAO etc.). For example, the Society for Promotion of Wastelands Development (SPWD) instituted four studies on CPRs, and ICRISAT trained the staff for these studies.

The landmark publication "Common Property Resources and Rural Poor in Dry Regions of India" by Jodha (1986) is one of the most widely cited papers by prominent commons scholars. One among them was Elinor Ostrom, in her Nobel Prize winning work on "Governing the Commons" from 1990 that challenged the conventional wisdom of the day by arguing that common property institutions are an alternative to privatization or state control of resources. Common property resources continue to decline in India but undoubtedly, Jodha's work has illuminated the costs to poor rural households of the erosion of these resources. Jodha has influenced CPR research and policy development

5. Anecdotally, I have been informed that the World Bank was influenced by these findings but I have not established this.
6. For detailed methodology, please refer to Jodha (1986)

outside India, for example in the Himalayas and Africa, where he has worked. His research is also referenced in literature from developed countries where managing CPRs continues to be controversial.

9.4 Efficiency analysis

Battese and Coelli were amongst the first to develop econometric procedures or models (stochastic frontier analysis) that allowed the identification of cross-section and time series effects in an econometrically sound manner. These methodologies were reported in Battese and Coelli (1992, cited 2210 times) and from Table 6, the citations to their papers account for almost a third of all citations to the 143 journal papers.

They used the VLS database because it was a large sample of households over ten years, which allowed them to identify household and time series effects that cannot be statistically identified when using either cross-section or time series data alone. Another attraction of the VLS database was that it was easier to access than databases held by government bodies.

Battese and Coelli have had a broad ranging influence on the way panel data methodologies are used to test economic theories and the impact on economic policies on households and firms over time that extends well beyond SAT households. Any student of econometrics would be exposed to the methodologies developed by them. I know of no way to value this contribution to the stock of scientific knowledge. Clearly, we would attribute a greater share of benefits to the intellectual contribution by Battese and Coelli. The VLS contribution can be thought of being the earlier development of these econometric techniques but there is no obvious way of valuing this.

To the best of my knowledge, the VDSA database is not being used either to measure trends in productivity or for stochastic frontier analysis. There are opportunities here for valuable contributions to our understanding of trends in productivity and the production frontier in South Asia particularly with respect to decisions about investment in R&D and extension and other policies promoting agricultural efficiency.

The VDSA database can be used to analyze trends in profitability, productivity, TFP, and terms of trade, TT, using methodologies suggested by O'Donnell (2010 and 2011). ABARES in Australia has published total factor productivity data by region and industry based on farm survey data for many years.

Some questions such analyses might answer are:

- Are changes in profit measureable from VLS data arising from TFP or TT (section 3)?
- Are changes in TFP arising from technical change (influenced by R&D) or technical efficiency (influenced by extension) or scale/mix efficiencies influenced by price changes?

A further extension is to follow O'Donnell and Griffiths (2006) in conducting stochastic efficiency analysis in a state continent framework (Chambers and Quiggin, 2000), which would allow the measurement of TFP that 'removes weather effects'. O'Donnell and Griffith (2006) found that rice farmers in the Philippines were much closer to the frontier than standard measures suggested. Applying state contingent theory would extend past work on risk and uncertainty, which has a strong VLS heritage, and remove any reliance of the expected utility hypothesis (consistent with Binswanger's findings for SAT farmers).

9.5 Production economics

Papers in the production economics grouping have been cited over 3,000 times (Table 6). I have not had time to review papers in this research area but note that papers (from Appendix 3) by Binswanger and colleagues (1986 and 1987) about the determinants of production relations in agriculture have been cited 1200 times, a paper by Shaban (1987) about sharecropping has been

cited 300 times, and a paper by Udry (1996) on the theory of the household has been cited 800 times. The Udry paper could have been classified in the gender research area.

It is likely that at least some of the papers in this research area made use of the time series cross-section nature of the data.

9.6 Nutrition and gender

Papers in these two research areas were cited over 500 times each (Table 6). The VLS contribution here is notable in that household data, allowing analysis of these issues were collected long before they became popular areas of enquiry. Ryan (1977) and Ryan et al. (1985), using VLS data, argued against the conventional wisdom at the time that there was a protein gap in the diets of rural households in India, and this had implications for breeding programs at ICRISAT discussed further below. Behrman and Deolalikar (1987, cited 400 times) questioned the view held by the World Bank at the time that as income increased so would the nutrition of rural households. They found that while aggregate food expenditure might rise with income, the expenditure on nutrients might not. This is one issue being investigated in the 2013-2014 Nutrition and Gender project mentioned earlier.

I have little experience in gender economics and have chosen not to venture here. However the VLS team was an early entrant to this research area. In Section 11.6, the analysis of the role of herbicides on SAT farms found that weeding was an important source of income for women and this was likely one factor dissuading ICRISAT from investing in weedicide research. In a recent study, Palacios (2012) using data back to 1975 from the six original VLS villages on how women used their time, found that the welfare of women was improved by better crop varieties, by mechanization, and by government programs.

10 Accelerated Technology Adaptation (K_t)

Traditional research activities add to the stock of knowledge or technologies, K, that are available to farmers and impact on productivity over sometimes many years. One of the direct outputs of the VLS/VDSA projects was an environment and infrastructure within the villages where technologies first developed at ICRISAT could be trialed and adapted in cooperation with the VLS households and the resident investigator and other VLS staff before being promoted to farming communities outside the VLS. Critically, the program fostered a whole farm perspective in agricultural research programs (noted in Walker and Ryan 1990, p.13 and detailed in Ryan 1984).

The counterfactual to the participatory whole farm research environment is the common scenario where researchers might conduct on-farm trials but these trials have no whole farm context and little input by the farmer into their design. The 'with VLS' scenario is likely to arrive at technologies fitting the relevant farming systems more quickly. Ryan (1984) argued that 'On-farm research is not simply for testing a subset of potentially viable and relevant technologies from amongst the shelf of prospective technologies emanating from onstation research. It is the dynamic feed-forward and feed-back between on-farm and on-station research which is an essential ingredient in successful farming systems research (p.121)'.

Only a small share of the benefits from trialing and later extending technologies from the VLS villages to SAT farmers can be attributed to the VLS/VDSA infrastructure. This concept of the benefits from accelerating the development and adoption of a technology was explained in Section 4. In Section 2.4.3, some of the many examples of technologies trialed in the VLS villages were listed (and can be found in Appendix Table 2). Here, the likely contribution of the VLS/VDSA infrastructure to a sample of these technologies is explained including:

- The more rapid adoption of Maruti pigeonpea in Maharashtra
- Broad bed furrow technology from the watershed program

10.1 Advancing the adoption of Maruti pigeonpea in Maharashtra

Maruti (ICP 8863) was an improved pigeonpea cultivar formally released by ICRISAT in collaboration with NARS partners in Karnataka state during 1986–1987. It was resistant to soil borne bacterial wilt, which has a devastating impact on the yield of pigeonpea. The incidence of this disease was rampant in Karnataka during 1980s and was endemic in parts of Maharashtra, Andhra Pradesh and Madhya Pradesh. However, ICP 8863 was not officially released, except in Karnataka, and efforts to popularize its spread did not receive any support from the formal seed sector or public extension agencies in the other states.

From discussions with VLS farmers in Kanzara (Maharashtra), an ICRISAT pigeonpea breeder recognized that Maruti had the characteristics sought by the farmers. He gave 5 kg of Maruti to the VLS resident investigator who distributed the seed to five village farmers. This was in 1987 before the start of the rainy season. The use of Maruti spread quickly over the next five years from Kanzara throughout the district of Akola to the neighboring districts of Buldhana, Yeotmal, Amravathi and Wardha (Padmaja 2012, p.173) mainly through kinship relations (either by blood or marriage), caste group affiliations, friends etc. Padmaja (p.173) noted that Maruti was still the dominant variety of pigeonpea in 2009. Had this opportunity not been provided by the VLS infrastructure and environment for farming systems research, the spread of Maruti in Maharashtra would likely have been much slower. Hence, farmers would have experienced losses from Fusarium wilt for much longer.

Charyulu et al. (2015) have estimated gains attributable to the VLS project from hastening the rate of adoption of Maruti in Akola and its surrounding districts of Buldhana, Yavatmal, Amravathi and Wardha. In developing a methodology, they were careful to avoid attributing to the VLS project the economic benefits that are rightly attributable to the pigeonpea breeding program. They attempted to isolate the benefits farmers received from adopting Maruti quickly because of the VLS village research environment.

The traditional approach in evaluating the economic welfare associated with a new crop variety has been to estimate the reduction in per unit production costs, k, arising from the new variety. This estimate of k, bc in Figure 2 (page 24), is an estimate of the vertical shift in the supply of Maruti and is the basis for estimates of the changes in the price and quantity produced of pigeonpea and associated changes in consumer (area abfe) and producer (area efcd) surplus using a standard model of the pigeonpea market. Typically, this change in potential total welfare over the target population is then scaled through time by the rate of adoption and an estimate of net present value is derived using discounting techniques.

This approach was also used by Bantilan and Joshi (1996). This approach is most sound when the technology has an impact on one enterprise, which is unrelated in production with other enterprises.

Evaluating the impact of a new variety of pigeonpea such as Maruti is made difficult by the complex farming system it is part of. In the Akola district, pigeonpea is usually intercropped with soybean or cotton. Moreover, as a pulse, it contributes nitrogen to following crops. In this situation, a single enterprise market model such as represented by Figure 2 is a crude approximation of what is actually occurring.

Charyulu et al. (2015) instead estimated the change in net income from using Maruti in inter-cropping systems including pigeonpea. This change in net profit, for say, a soybean + pigeonpea system, can be estimated from a gross margin budget (income less variable costs) for a hectare of the soybean/pigeonpea system and then scaled to the target area. This approach was explained in Section 4 and is repeated here for convenience.

Effectively, this estimate of the change in net income is area *abcd* in Figure 2, the change in unit costs, k, times Q, the size of the industry. It underestimates total welfare gains by the triangle, *bfc*, which are potential gains as pigeonpea systems, now more profitable because of Maruti, are grown more widely by farmers at the expense of cropping systems that do not include pigeonpea. The area *abcd* are the total industry gains enjoyed by consumers and producers. If the price of pigeonpea does not fall much (demand is highly elastic), then most of the gains accrue to farmers.

There are a number of steps in evaluating the VLS contribution to the adoption of Maruti in the study area. First, the area of pigeonpea intercropping systems in the five districts was estimated, then, the adoption of Maruti within these systems was estimated. The change in profit from the use of Maruti on a per hectare basis was estimated and scaled up to the gains from Maruti in the districts by applying the area of pigeonpea systems and the adoption of Maruti. This gives the total gain from Maruti in these districts. Finally, the acceleration in the rate of adoption of Maruti attributable to the VLS project was estimated and applied to these estimates of total gains to arrive at an estimate of the contribution of the VLS project, effectively the area between the adoption paths in Figure 3 (page 25).

The data on Maruti adoption rates, areas sown to pigeonpea and shares of total pigeonpea area accounte0d for by the alternative pigeonpea systems, and the net gain budgets were obtained from interviews with farmers in the villages, the VLS databases and from scientists and economists. Focus group meetings with farmers were held in the villages of Kinjara, Kinkhed, Lasanpur, and Nimbha. Field reconnaissance surveys were extensively conducted to validate adoption information at Akola and neighboring districts. Secondary data were also collected from the Directorate of Economics and Statistics, Akola and Maharashtra State Seeds Corporation/Mahabeej (MSSC) to complement the focus group meetings. Since Maruti was first introduced in Akola, adoption was expected to be earlier there than in the other districts. The budgets for the four villages in Akola were the basis for estimates of net gains from Maruti for all five districts.

The contribution of the VLS project was to advance the rate of adoption of Maruti in Akola and perhaps the four neighboring districts. This adoption parameter is most uncertain. One of the VLS farmers who first used Maruti said that it may have been a further five years before they got Maruti. Charyulu et al. (2015) assumed a lag of only one year and hence, the benefits attributable to the VLS project were estimated by lagging the stream of benefits to Maruti by one year and taking the difference. They further assumed that the rate of adoption would have been the same from 1995 and hence, no further benefits were attributed to the VLS project from then.

All estimation was based on budgets expressed in 2013 rupees and the stream of benefits from 1986 was compounded forward at 5% to arrive at a 2013 present value. The variable VLS costs were based on time spent in nominal rupees converted to 2013 real rupees using the GDP deflator for India and compounded forward to present value terms.

In Akola, the benefits attributable to the VLS for a lag of one year amount to Rs 103 million or US$1.7 million and in the other districts they total Rs 398 million or US$6.6 million or US$8.3 million in total. This is about 2.56% of the total gains from the introduction of wilt resistant Maruti in Akola and the other four districts.

The variable costs amounted to US$152,814. The VLS presence and efforts were in the villages of Kanjara and Kinkhed in Akola. A conservative approach would be to attribute only the benefits from more rapid adoption of Maruti in Akola, US$1.7 million, to the VLS project. If the Akola benefits are related to the variable costs incurred, the benefit cost ratio is 11.1:1 but no allowance has been made for a share of overhead costs of the VLS projects of US$14.7 million. The benefit cost ratio increased to 54:1 across the five districts.

10.2 Watershed management

Watershed management is an important area of research at ICRISAT. There are many components to this research program but the broad objective has been to increase yields in dryland areas through conserving moisture, managing excess water, and protecting soils. There have been several economic assessments of this program (or components of it) including those by Joshi et al. (2002), Bhole et al, (1998), Joshi and Bantilan (1998), Ryan and Subramanyam (1975), Ryan et al. (1980) and Walker et al. (1989). These papers indicate an ongoing relationship whereby the VLS group is likely to have influenced the direction of watershed management research and hastened the adaptation and adoption of technology. Here, the present report focused on one technology, broad bed furrow (BBF) technology, which was trialed in three VLS villages for about four years from 1978.

Joshi et al. (2002) evaluated a suite of ICRISAT watershed management technologies based on field trials with other research institutions from 1979 to 1983 at various sites in Andhra Pradesh, Maharashtra, Madhya Pradesh and Karnataka. They found some components of the package were profitable at some sites. BBF technology was not widely adopted but they found few farmers were aware of it. There is also a joint review of these technologies by the Farming Systems and Economics Research Programs in the 1981 ICRISAT annual report.

Before these field trials, BBF (and perhaps other components) was trialed in three VLS villages, and according to one of the researcher involved (Murali Sharma), much was learned from these trials. The objective of the BBF technology was to grow two crops in a year in areas such as Hyderabad where rainfall is about 800 mm annually. Large economic gains were expected from such a system. The technology first required a change in land management. Fields were developed to have a gentle slope with a bed and furrow layout. The furrows and slope improved drainage and because the bullocks walked in the furrows, there was little soil compaction in the beds. With less compaction, fields could be cultivated and planted before the start of the June to September rains, allowing a crop to be grown during the rainy season. The technology seems most applicable in higher rainfall areas with black soils that can be difficult to work in because prior to the monsoon rains in June they are too hard to cultivate with typical village equipment and once the rains start, they become muddy and sticky because they are poorly drained. Their attraction is that they do hold moisture and hence, after the rainy season, a crop can be grown on moisture conserved during a fallow. This was the traditional farming system that gave but one crop a year. In contrast, double cropping in the drier areas has been a traditional practice in Indian agriculture. While the BBF technology has many attractive features, there were also sound reasons why it has not been adopted as widely as might have been expected. For example, it is not practical for cotton growers who cultivate lengthways and crossways.

10.2.1 The role of the VLS project

This two-crop technology was ready to be trialed in a village setting in 1978. However, at that time ICRISAT scientists were not usually permitted to engage directly with farmers in research and extension of new technologies. The VLS Program, however, was working in six villages and provided a very valuable vehicle to test the watershed management technology in real world situations.

The technology was tested in the villages of Aurepalle, Shirapur and Kanjara. Neither of these were ideal locations to test the technology from an agronomic point of view. Aurepalle has predominantly red soil rather than black soil for which the technology was first developed. The rainfall at Shirapur was variable and lower than desirable and the soils at Kanjara, while black, were not deep. Other technologies such as the 'tool carrier' were also trialed during this project.

The alternative to the VLS villages was to work with the national CRIDA institution but the close supervision of the trials by the VLS resident investigator and other support staff would not have been available. Hence progress with the trials would have been much slower and perhaps the benefits of the technology less obvious to the village households were the technology not properly implemented.

The trial of watershed management in these three villages was regarded as being highly successful. The trials continued over a period of four years with a high degree of cooperation between the watershed scientists and the economists associated with the VLS project. It is most likely that these trials had some influence not only on the adaptation and adoption of the technology but also on the direction of watershed research. No attempt has been made to estimate the gains from the VLS contribution to the development of watershed management technologies such as BBF.

BBF techniques are a component of the Groundnut Production Technology package (GPT or GNPT) collaboratively developed by ICRISAT and the Indian NARS[7]. The technology, developed in 1986, and widely tested on farmers' fields during 1987–1991, integrates various crop and resource management options, including land, nutrient, insect pest and disease, seed, and water management. Based on a survey conducted in Maharashtra, the study observed partial and step-wise adoption of different components of the technology that ranged between 31% for the raised-bed and furrow technology to 84% for improved varieties. Compared to the prevailing technology, GPT gave 38% higher yields, generated 71% more income, and reduced unit cost by 16%. The technology also contributed to improving the natural resource base, and eased certain women specific agricultural operations. The total net present value of benefits from GPT technology was estimated to be more than $3 million, representing an internal rate of return of 25%. The study suggested important lessons for research and technology transfer policies and for the development of future research priorities. Some of its components are now used in Indonesia and Vietnam. I made no attempt to attribute some of these benefits to the VLS/VDSA projects.

7. Some of this material was provided by GD Nageswara Rao

11 Program Priority Setting (Z_t)

There are formal and informal ways by which the VLS/VDSA team was likely to have influenced the direction of research at ICRISAT and in national and CGIAR institutions. Formal influence occurs through the normal processes of reporting on research through publications and seminars and as a partner in the development of research programs. However, informal influence through daily encounters between staff, particularly program managers and higher, is likely to have been just as influential.

Changes in research priorities first impact on Z, the stock of knowledge and experience of science managers in allocating research funds. Any increase in the efficiency of research activities that increments to K, the knowledge stock available to farmers, are larger and occur sooner.

While the economic impact of a change in research priorities may be estimated from the gains from new technologies, judging the influence of VLS research on priority setting within ICRISAT is a highly subjective or probabilistic process. The VLS research is only one source of information used by research managers in establishing their research portfolios and hence, some subjective attribution process is required if the VLS contribution is to be identified.

The ICRISAT Annual Reports provide some evidence that the VLS project was likely to have influenced the direction of research at ICRISAT. The 1981 Report in particular contained a lengthy review by the Farming Systems and Economics Research Programs of the previous six years of research into farming systems. A range of technologies, including watershed management technologies (Section 10.2), were evaluated for their potential for adoption by SAT farmers, and in many cases, the assessments were based on VLS data and village experiences.

Areas where the VLS/VDSA projects have been influential in setting research directions in ICRISAT and elsewhere, such as in the CGIAR, include:

- Breeding for yield vs. protein
- Crop/livestock interaction
- Implications of farm size for technology and policy development
- VDSA influence on CGIAR CRP programs
- Intercropping research
- Herbicide research
- Bioeconomic modeling

11.1 Breeding for yield vs. protein

Findings from analyses of the nutritional status of households in the VLS villages guided research at ICRISAT. A survey of diet, health and nutrition in the villages by Ryan, Bidinger, Rao and Pushpamma (1985) found that their diets were deficient in energy, calcium, β-carotene, B-complex vitamins, and vitamin C. Their study showed that the real scenario was different from the conventional wisdom that the diets of poor people in developing countries were deficient in protein. Moreover, Ryan (1977) pointed out that there generally was an inverse relationship between yield and protein. Hence, he argued that breeding programs focusing on yield and yield stability would enhance nutritional welfare more than a focus on protein. An increase in yield would deliver increases in protein, lysine and energy.

In the ICRISAT Annual Report for 1975, there is a discussion of the yield vs. protein issue:

'Our findings suggest that ICRISAT's breeding strategy should focus on yield enhancement, together with disease and other environmental resistances to reduce the variability of yields. We question whether improved protein and lysine content, while desirable in themselves should rate a high priority. Instead, we suggest that the carbohydrate content of grain should receive more attention to reduce deficiencies in calories throughout the semi-arid tropics (p.85)'.

Ryan's work based on data from the VLS villages was said to be influential in forestalling a proposed change in the direction of breeding programs at ICRISAT away from a yield focus toward a protein focus.

11.2 Crop/livestock interaction

In 1970s and early 1980s, the focus of crop breeding programs for sorghum and millets at ICRISAT and also within national programs was on grain yield and not so much on the stover or fodder component. For the traditional varieties of sorghum and millets, farmers valued both grain and straw. While the grain was used as human food, the stover was used as livestock feed. The importance of stover in SAT mixed-farming systems and the disincentives to using some new high yielding varieties was reported in several (15) publications from the VLS team (including Parthasarathy, 1985 and Kelley et al. 1993)

Although the breeding programs emphasized dual purpose cultivars for sorghum and millets, i.e., both grain and straw, the stover component was not given emphasis in improved high yielding cultivars. Thus, a number of improved cultivars for sorghum and millets were not adopted by the farmers despite higher grain yields owing to lower stover yield and poor stover quality. Kelly and Parthasarathy (1994) noted that improved sorghum cultivars were adopted by under 50% of farmers in some states in India and used VLS household data to test whether straw yield and quality influenced choices by farmers about sorghum varieties. They found that these considerations were influential in choosing varieties, particularly in low rainfall marginal environments where animals had to be fed.

At the same time owing to income growth and urbanization, the demand for livestock products, particularly milk was rising, as was the demand for poultry meat. While the milk sector grew at more than 4%, the poultry sector grew at 8–10% per annum. This demand-driven livestock revolution drove the derived demand for livestock feed including for stover/fodder. As a consequence, the stover to grain price ratio for sorghum and millet crops increased. Both the nominal and real prices of stover increased while the real prices of grains declined. VLS meso-level data for the Sholapur market in Maharashtra indicated that the grain to stover price ratio declined from 6:1 in early 1970s to 3:1 by early 1990s. A similar trend was also found for thepearl millet grain to stover price ratio in Rajasthan although the decline in the ratio was less steep than for sorghum.

These findings had a salutary effect on the breeding programs, causing them to look more closely at the stover component of new improved cultivars of sorghum and millets. It is highly likely that this economic research based on VLS household data was influential in the direction of sorghum breeding at ICRISAT at that time.

In the 1990s and early 2000s, this trend was also observed for groundnut haulms. An improved cultivar ICGC 9111 was preferred by farmers that gave 25% higher pod yield, 20% higher haulm yield and 0.5 liters higher milk yield due to superior fodder quality. The farmers had earlier rejected several improved cultivars and preferred ICGS 9111 due to its dual purpose characteristics.

In late 1990s, ICRISAT created a research area on crop-livestock linkages, specifically looking at crop residues and crop–livestock linkages in small farms in a systems perspective. This area of research was later merged with the economics and resource management programs. At the same time, ILRI (International Livestock Research Institute) became an important partner of ICRISAT to look at crop –livestock linkages by addressing the nutritional value of crop residues of ICRISAT mandate crops. ILRI opened a regional office at ICRISAT Patancheru to strengthen the collaboration between the two institutes.

As evidenced by the publication record over two decades, a significant body of research was undertaken by the VLS team. The findings from economic assessments of stover/fodder value and farmers preferences for fodder quality based on insights from VLS and meso-level data seems likely to have influenced the direction of breeding programs towards a consideration of both stover and grain yields and in the direction of research programs focusing on crop/livestock linkages at ICRISAT and more broadly in the CGIAR system.

11.3 Implications of farm size for technology and policy development

Ryan and Rathore (1980) (as reported in Ryan 1984) used VLS data to test the importance of farm size to how the benefits of technology were shared. According to Ryan (1984, p.118) they found that 'it is not possible to infer that small farms require technologies which …. differ in substance from those of large farms'. They pointed out that the land to labor utilization ratio was more significant to household welfare than the land to labor endowment ratio. This implied that policies aimed at enhancing the performance of factor markets and the accessibility by owners of small farms are likely to be more successful in achieving a more equitable distribution of the benefits of technological change than the attempts to design basically differentiated technologies for small farms (p.118).

These arguments are likely to have influenced the direction of farm policy R&D in the economics group at ICRISAT and elsewhere. They may also have influenced the direction of production research at ICRISAT but no clear statements to this effect have been found.

11.4 VDSA influence on CGIAR CRP crop programs

Anecdotally, analysis of VDSA data has been used to influence the direction of CGIAR CRP crop programs for dryland cereals, legumes, and rice. I have not received or discovered material regarding the VDSA contribution to the dryland cereal and legume CRPs. However, there is stronger evidence that the VDSA project in Bangladesh has influenced rice R&D programs in Asia as a whole, particularly in Bangladesh, through different ways.

In recent years, analyses of data for Bangladesh from the VDSA databank are likely to have influenced the direction of the upcoming second phase of the rice CRP known as the Global Rice Science Partnership, GRiSP[8]. Data on inputs to rice farming such as decreasing farm size, increasing wage rates and off-farm employment of males, increasing reliance on women in agriculture, an aging population, stagnant rice yields, and greater market orientation has encouraged GRiSP to consider these trends. However, it is not clear to me how research programs can be devised that do not reflect some compromise between an efficient profitable rice industry in Bangladesh and concern for the social issues mentioned. Bangladesh is currently developing its national rice development strategy. The VDSA project has been providing inputs to develop this strategy, which puts priority on increasing productivity of smallholder farmers, development and dissemination of labor-saving technologies, adoption of water-saving technologies, reducing cost of rice production, and increasing adoption of hybrid rice varieties.

The VDSA data is also used to assist priority setting in Bangladeshi institutions. For example, the Ministry of Food, Bangladesh released a National Food Policy Plan of Action and Country Investment Plan Monitoring Report for 2014 using VDSA data as reference for the reliability of the plan's rice data. The VDSA Project is also contributing rice related data and information to a consortium in Bangladesh known as "Agricultural Research Management Information System (ARMIS)".

11.5 Intercropping research

Inter-cropping is a key element of traditional farming systems in India, especially on small farms. Pigeonpea is often grown as part of an intercropping rotation. The traditional intercropping systems are complex. Numerous crop combinations are used in a single village. Intercropping, besides effectively meeting the needs of subsistence farmers, plays an important role as insurance against risk.

Jodha (1980), using data from the VLS villages, pointed out the importance of intercropping. His findings on the extent and profitability of intercropping and his call for agronomic research in an intercropping context likely had some influence on the direction of crop research at ICRISAT. Ryan (1984) argued that these findings of Jodha (1980) pointed to the importance of inter-cropping research for such farms. Inter-cropping economics research features in ICRISAT Annual Reports from 1975.

8. Much material in this section was provided by Dr. H. Bhandari, IRRI who supplied a set of five research reports to support his findings.

11.6 Herbicide research

Whether ICRISAT should allocate more resources to herbicide research and weed science was a relevant issue in the 1970s[9]. Analyses based on VLS data indicated that herbicide research in India's SAT was not a priority at that time (Binswanger and Shetty 1977). The analysis of VLS and experimental data indicated that the use of herbicide was not profitable in any of the more intensive dryland cropping systems. In addition, VLS data on the employment of labor, which has always been gender specific, showed that earnings from hand weeding constituted a significant share of women's wage income in all the villages. Thus, any reduction in hand weeding hours made possible by herbicides would primarily reduce work and income opportunities of the most disadvantaged labor group, female agricultural workers.

These findings likely influenced ICRISAT not to invest in herbicide research. Presently, herbicide use is still negligible in the villages with the exception of irrigated cultivation where partial adoption of herbicide has occurred since the mid-1980s.

11.7 Bioeconomic modeling

The CGIAR Research Program on Dryland Systems has adopted a systems approach to enhance agricultural productivity in South Asia through technological interventions[10]. It is important to identify options that are manageable within the context of the farmer's resource base and the household's objectives that could improve farm household well-being. The VDSA databases are being used to support the development of a bioeconomic model of the semi-arid agro-ecosystem in the Bijapur district of Karnataka state in India that will be used to guide research priorities for such areas. Bijapur is in the lowest rainfall zone in Karnataka with an average annual rainfall of 585 mm. The components of the model and their interactions with the environment are identified through stakeholder and expert consultations. This bio-economic model is designed to represent key features of smallholder farming such as heterogeneity, non-separability of production and consumption decisions, and constraints on resource use. Synergies and tradeoffs for a range of technological interventions and resource constraints will be assessed, including changes in current enterprise mixes, potential for intensification, and environmental impact. Indicators generated from the model are useful for effective farming system design and up scaling to larger areas, when linked to the typology. The model developed has the potential to be adapted to other resource conditions and further extended to accommodate analysis such as the impact of climate change.

9. Much of this material was supplied by the VLS team
10. Much of this material has been supplied by Dr Ramilan Thiagarajah, ICRISAT

12 Accelerated Rural Policy Development (J_t)

Policy makers take advice from many government and non-government sources. Identifying which sources have been influential is a highly subjective process. Many of the intermediate outcomes from VLS/VDSA activities have policy implications. Tracking changes in the welfare of rural households and how they smooth consumption when incomes are volatile using common property resources and by their choices of technology are obvious examples. However, those analyses which exploit the unique panel data characteristics of the VLS/VDSA databases allowing a better understanding of how rural households manage weather and price uncertainty, as distinct from descriptions of trends in welfare that are discontinuous in time and between households, ought to have been more influential in policy areas seeking to mitigate uncertainty and reduce poverty. It should be noted that not all VDSA papers exploit panel data properties, but they may still be influential if alternative analyses are based on aggregate rather than individual household data. Research that tests hypotheses questioning the conventional wisdom is also more likely to be influential.

Research with policy implications increases J, the stock of knowledge and experience of policy makers. Changes in policy are likely to be reflected in changes in the prices of inputs and outputs (sometimes implicitly). In addition, changes in prices also influence profitability through their impact on the terms of trade as in Equation 1. Their influence on profitability may also arise through changes in mix and scale efficiencies, components of total factor productivity (TFP). Most often, the VLS contribution to policy change may be thought of in terms of the number of years by which reform has been advanced (Figure 3).

The VDSA team has undertaken a range of activities designed to influence policy makers. In particular, it has organized several policy dialogues, symposium and workshops with the help of other national co-organizing partners – ICAR, India; the International Food Policy Research Institute, South Asia office in New Delhi; and the Institute for Human Development (IHD), Delhi. It has also invited senior policy makers, policy analysts, the Secretary, Department of Agricultural Research and Education, the Secretary of the Ministry of Agriculture Development, former ministers and members of national planning commissions, and the heads of several governmental agencies, involved in agricultural and rural development in India (Table 11). Engaging policy makers and other stakeholders in these platforms increases the likelihood of influencing the policy decision making in the region.

Areas where the VLS/VDSA activities are likely to have had an influence on rural policy development include:

- Trends in the welfare of rural households
- The MGNREGA scheme and other safety net programs
- Crop insurance
- Common property regulation
- Free trade between states
- Community Driven Development

12.1 Trends in the welfare of rural households

Important outputs of the VLS/VDSA projects have been papers reporting trends in parameters of welfare such as:

- Income;
- Sources of income;
- Changes in assets and liabilities;
- Changes in farm enterprise mix;
- Gender dimensions to these parameters

Deb et al. (2014) is a good recent example of this set of papers. They focused on the original 6 VLS villages for the period of 1976–2012 (except for the gap between the two projects). They provided detailed trends in income and poverty that showed considerable gains in most villages. They further tracked other important parameters such as cropping patterns, rural credit, assets, mechanization, education, and health. These papers serve a useful purpose in making the factual information about trends in the welfare of rural households in many districts in India, Bangladesh and Africa widely available in contrast to aggregate measures of a smaller set of these important parameters. As mentioned above, in recent years, the NCAER and the LSMS databases have become competitors of the VDSA databases but they are likely to be imperfect competitors because their panel datasets are shorter in length and not as comprehensive in respect of important household, as distinct from farm variables, such as off-farm income, household assets and liabilities, and gender and nutrition dimensions.

However, it is difficult to identify the influence on policy of this set of papers from the VDSA team. While comprehensively tracking trends in important parameters, implications for policy are left implicit and rarely identified and explained. Perhaps this set of papers may form a platform for a more analytical program of research (either within the VDSA team or externally) fully exploiting the panel data properties with clear policy implications in areas where household behavior with respect to risk, for example, is critical to policy design. Efforts in this area are underway as evidenced in the next subsection dealing with social safety net programs.

12.2 The MGNREGA scheme and other safety net programs

The MGNREGA scheme (the Mahatma Gandhi National Rural Employment Guarantee Act) is described as "perhaps the largest and most ambitious social security and public works program in the world" (Ministry of Rural Development, 2012, MGNREGA Sameeksha, p. ix). It aims to guarantee the 'right to work' and ensure livelihood security in rural areas by providing at least 100 days of guaranteed wage employment in a financial year to every household whose adult members volunteer to do unskilled manual work. Under the scheme, the unemployed work on defined categories of public works or infrastructure. One of MGNREGA predecessors at a state level was the Maharashtra Employment Grant Scheme (MEGS), which was initiated in the early 1970s to combat high unemployment as a result of severe droughts.

MEGS predated the VLS project but Binswanger-Mkhize (2013, p. 65) pointed out that from the earliest days of the VLS project, household data were being used to demonstrate the impact on households of the scheme. Walker and Ryan (1990) found that unlike the situation in other states the level of distressed land sales in times of drought was lower in Maharashtra, indicating that MEGS was successful in assisting households ride out periods of very low income.

This type of analysis has continued also in the second generation VDSA project with external support. In India, many studies have reviewed different dimensions of the impact of MGNREGA including its effectiveness and economy wide benefits and financial viability of the program, and its sustainability in the long run (Ministry of Rural development, 2012[11]). However, few of these studies have used high frequency panel data such as is available from the VDSA to provide insights into the impact of the MGNREGA and other safety net programs on rural households.

Presently, the VDSA team at ICRISAT is undertaking a project titled 'Impacts of Social Protection Policies on income, employment, food security, gender and livelihood assets of the rural poor in Semiarid Tropics of India' (CRP2#30)[12]. This study has analyzed the impacts of MGNREGA at a) micro level; b) community scale; and c) meso (or sub-national) scale, using VDSA household and meso-level data supplemented by a survey in the 18 VDSA villages in SAT India. The specific policy questions analyzed in detail and reported in a series of papers are:

11. MGNREGA Sameeksha: An Anthology of Research Studies on the Mahatma Gandhi National Rural Employment Guarantee Act, 2005 2006–2012' published in 2012 provides a bibliography with brief abstracts of many analyses of dimensions of MGNREGA but predates the VDSA analyses.
12. Much of this material has been provided by Dr Mahdusudan Bhattarai of ICRISAT.

- What are the implications of MGNREGA on landless labor, women and other vulnerable members of the society?
- How effective is the MGNREGA as a social safety net as it has been currently implemented across the study villages?
- What are the implications of MGNREGA on agricultural wage rates and labor markets across the selected villages?
- What are the implications of MGNREGA on the borrowing behavior of rural households, agricultural activities, and rural livelihoods in the selected communities?
- What are the direct and indirect impacts of the MGNREGA interventions in the targeted communities?
- What is the impact of the program on consumption of food and the income and assets position of the households participating the program?

One important area of research was to investigate the impact of MGNREGA on rural labor markets (Narayanamoorthy and Bhattarai 2013; Reddy et al. 2014a, 2014b, 2014c, 2014d; Reddy 2014). Some landowning large farmers blame MGNREGA for the recent increase in agricultural wage rates but other factors such as increased cropping intensity, particularly an increase in cotton growing, have contributed to rising rural wages. Analysis based on VDSA meso-level data from 2001 to 2011 (Narayanamoorthy and Bhattarai, 2013) found that real wage rates have increased substantially during the post-MGNREGA period for both male and female agricultural laborers in all the major farming operations, although the increase was more for female laborers. The regression analysis has suggested that the average days of employment per household by MGNREGA, productivity of food grains, and road density have all contributed to the growth rate of wages.

A series of papers have examined the impact of MGNREGA on household welfare (Viswanathan et al. 2014; Surendra et al. 2014 a, 2014b; Bhattarai, Varalakshmi and Bantilan 2013).The key findings at the household level include:

a) During the period of empirical analyses from 2009–2011, the debt ratio (ratio of total debt to total asset) of the households who participated in MGNREGA was substantially lower than their counterparts who did not participate

b) The participating households have been able to reduce their dependency on non-institutional sources of credit more than their counterpart neighbors, leading to less dependency on the local landlord (i.e., social empowerment).

c) Per child expenditure on education in the participating households has been increased substantially (Rs 900 /child) from 2009 to 2011 compared to non-participating households;

d) MGNREGA participation has led to long-term asset accumulation and human capital formation.

A field survey (Surendra et al. 2014 (b)) of selected villages in AP and Karnataka found that at a community level, there have been some inefficiencies in the way MGNREGA and other social security programs have operated. Those households that are slightly better off were able to gain better access to MGNREGA and other SSN programs than the poor and marginal households. Those living hand-to-mouth still struggle, and many of them are out of the reach of the institutional and governmental SSN program indicating inefficiency in the targeting of several of these programs.

The results across the four villages in AP suggest that MGNREGA is an important source of support for the program participants (beneficiaries), especially for those who are from the lower strata households in the community, and for women or the elderly who cannot seek work away from the village. In some villages, especially in the dry season (i.e., Dokor village of Mahaboobnagar district) when MGNREGA work activities were in full swing, seasonal migration dropped up to 50% within 2–3 years of implementation of MGNREGA. In 2009, only around 300 people in Dokur migrated out of villages during the dry season, whereas in 2006–7, over 600 people migrated out of the village during the dry season when little farming sector employment was available in the village. In places close

to a large urban centre, for example, Aurepalle near Hyderabad, people still regularly migrate from those villages to Hyderabad for education and higher wages. This type of developmental migration is not affected by MGNREGA activities in the surveyed villages, partly because the participants in MGNREGA are usually the old or women who cannot travel to labor markets due to various social and cultural factors.

The publication record from the project (including a forthcoming book) indicates that these analyses based on the use of panel household data from VDSA database have added to the stock of scientific knowledge. The project team has also undertaken a range of activities designed to influence policy makers. In particular, the findings from this research were presented at the national symposium and policy dialogue in New Delhi on 15–16 September 2014. I have made no attempt survey the literature to determine whether this project provides a different viewpoint nor have I formally assessed the extent and direction of influence.

12.3 Crop and rainfall insurance

Beginning with the work of Binswanger-Mkhize (1980) described in section 9.2, there has been a continuing contribution by the VLS project to the debate about how farmers protect themselves against risk through crop and rainfall insurance. VLS annual panel data allows the variance of output, profits and income to be measured, which is not possible otherwise. Important contributions have been made by Walker and Ryan (1990); Bakker (1992) Hess (2003).This work was based on empirical analysis of the impact of weather risk on VLS households and how these families might benefit from alternative types of insurance when risks are often covariant between households.

Townsend (1994) found that that, except for the landless, villagers seemed to be able to smooth out consumption reasonably well and that consumption by better-off households is separable from their production decisions. This paper has been cited 1,865 times because it was one of the first papers to use the VLS panel data (Binswanger-Mkhize, pers. comm.). Binswanger and Rosenzweig (1992, cited 894 times) found that because of this separability between consumption and investment, the better-off farmers were able to have a profit maximizing portfolio while the poorer ones had to bias their investments to those that also reduce risk, experiencing a loss of profits of about 30 percent. As indicated by the level of citations, these papers were influential among scholars in development economics not just in the SAT but worldwide. I can't judge what influence the papers had on policy and thence the welfare of poor farmers.

This ongoing contribution has been summarized by Rao et al. (2006). They pointed out that the efficiency gains associated with the Green Revolution and the subsidization of the mainly irrigated Green Revolution products and inputs has left rain-fed SAT farmers more exposed to risk. Prices of rain-fed grains have fallen relative to subsidized wheat and rice prices. This scenario has exacerbated the pressure on traditional forms of local risk sharing from covariant weather risks. In addition, rainfed farmers have less access to credit provided by the large financial institutions. Hence, it is difficult for poor SAT famers to smooth out consumption over years without resorting to running down assets often at distressed prices. Crop insurance was introduced in India in the mid 80s as a co-product with loans to cover pre-harvest crop expenses. Rain-fed farmers were rarely eligible for such loans and hence, crop insurance was rarely taken out by them. The crop insurance scheme was subsidized at the rate of about 5 (indemnities):1(premiums).

Those researchers who have based their analysis on the VLS data have recommended that rainfall rather than crop insurance is most suitable for SAT rain-fed farmers and for landless labor households. Its attractions include transparency and less risk of moral hazard and adverse selection. One commercial product is being trailed in Andhra Pradesh but its premium is based on actuarial rates, making it uncompetitive with subsidized crop insurance. Despite this insight, my understanding of the literature is that despite an enormous research effort over many years in many countries, successful insurances schemes for agriculture are yet to be devised. Many existing schemes are dependent on government support.

12.4 Common property regulation

As discussed in Section 9.3, Dr Jodha's common property work has been widely recognized and is certainly regarded as having been influential in our understanding of the importance of common property resources to poor rural households. I have not attempted to identify changes in policy with respect to common property resources nor the even more difficult task of attributing some share of the impact of any policy change to Dr Jodha's influence relative to other sources of policy advice.

12.5 Free trade between states

In the late 70s, the VLS team, particularly von Oppen (1978 and 1983) contributed to the debate on free trade between Indian states. Trade between Indian states was liberalized in 1977 but von Oppen was concerned about the possibility of policy retrenchment. He used spatial equilibrium models based on VLS data to demonstrate that agricultural productivity was higher when markets were less regulated and rural infrastructure was improved. It is not possible to discern the extent to which von Oppen's work was influential but interstate trade remained free.

12.6 Community driven development

Similar to the development of farmer participation in research, interest in allowing communities more control over how funds should be used to aid their development. The approach of community driven development (CDD) emerges from the wider discourse on integrated development of rural and urban areas that emphasizes greater participation and control by the communities over the planning decisions and investment resources (World Bank 2000; Casey et al. 2012) as an alternative to centralized service delivery systems (Binswanger and de Regt 2012). In the spirit of CDD, the VDSA project provided $7000 each to six of the original VLS villages in Maharashtra and Telangana in December 2010. The villages have used the grants on projects benefiting the whole village. Projects include establishing drinking water supplies in AP villages, a village computer center in Kinkhed and a proposed dal mill in Kanzara (Maharashtra villages). In five of the six villages, about 400– 500 households per village have directly benefitted from the small grants. The process of monitoring how the grants have been used is continuing and an impact assessment of the trial is planned.

The VLS/VDSA village infrastructure has likely made implementing the trials easier, perhaps increasing the funds available to the villages through lower project establishment costs. It will also simplify impact assessment because of the availability of baseline household data. Perhaps the VLS contribution to the success of these CDD trails is in terms of lowering the cost of achieving and assessing the welfare gains from the CDD activities. The opportunity cost of the CDD trials is the return that the VLS/VDSA grants could have earned in other activities. A report by Dr. Srinivasa Reddy Srigiri,"Evolution of collective action institutions for community driven development: lessons from the village grant experiment of ICRISAT" will be published in 2015.

12.7 Land economics

A paper by Jodha (1981), although only cited 45 times has characteristics likely to have made the paper influential. Jodha addressed the question of who was leasing land and found that very often it was larger farmers leasing land from smaller farmers rather than the reverse as commonly believed. These tenancy arrangements often increased efficiency at a time when there were restrictions on land owning and accumulation. It was believed that large landholders exploited the small poor tenants. At that time, tenants could claim ownership after some years of permanent tenancy. I have not pursued whether Jodha's paper had an impact on policy with respect to tenancy and land ownership. Perhaps it was influential in forestalling further regulation.

Jodha's (1981) research would not have been possible without the VLS infrastructure. Because of the policy climate with respect to tenancy and land ownership, reliable data on these issues were unavailable. Jodha noted that it was only after some years that participating households were comfortable to provide accurate information to the project team.

13 The Potential Flow of Outcomes from the VDSA Project

The focus of VDSA activity, as stipulated in the Bill & Melinda Gates Foundation proposal, was to extend the gathering of data to new villages in East India and Bangladesh, requiring the training of a new team of village investigators and support staff. The meso databank was also extended. Considerable effort was required to make the data available in a user friendly format at the website and through an on-line knowledge bank with some interactive analytical capabilities. These activities have been described in section 6.

The terms of the impact assessment reported here were to assess the impact of both the original VLS project and the newer VDSA project. Most of the likely impacts that I have identified have derived from activities undertaken using outputs of the original VLS project. As was noted above, there were considerable lags between the availability of the original VLS data and the publication of many highly influential scientific papers and other outcomes based on this data. This pattern is likely to be repeated for the recent VDSA data. Hence, while the activities and outputs of the VDSA project can be reported, likely impacts and outcomes are just beginning to emerge.

Some likely impacts of the VDSA project identified above include its influence on research priorities, e.g., within the CGIAR CRP rice program and other rice research institutions in Bangladesh (section 11.4). Potential impacts on policy development have been described in earlier sections on trends in household welfare (12.1), and social safety net (12.2) and community driven development programs (12.4). In Section 6.2, it was noted that, as at January 2015, there were almost 800 registered users of the data and of them, over 200 were PhD students. This indicates that impacts based on analytical research using the databases are likely to grow in the future.

The VDSA team has also engaged in an array of early stage research and communication activities that underlie expectations of future project impacts. This array of activities is detailed in Tables 8 – 10 provided by the VDSA team[13]. In particular, as shown in Table 8, there have been over 270 papers including 9 journal papers from the VDSA team and a strong training record. As mentioned in section 12.1 and detailed in Table 11, the team has worked with partners to hold conferences and symposia attracting key policymakers especially from India, increasing the likelihood that its analyses will be influential and creating awareness of the potential of the VDSA databases.

A weakness of this current impact assessment process is that I have not attempted to clearly identify in an ex ante sense, specific research areas or projects of existing users of the VDSA databases the PhD students for example, which are likely to have significant impact in the future. However, the same set of factors that I have used ex post to identify activities likely to be of high impact, can be used to assess ex ante the likelihood that activities will be influential in the future. This set of factors includes:

- Whether they will use the unique time series and cross section characteristics of the data to analyze choices by rural households when weather and prices are uncertain;
- Whether they will use used the village infrastructure allowing technologies to be trialed, special surveys to be conducted and sensitive data to be collected accurately;
- Whether the village household perspective they provide will not otherwise be available;
- Whether they can exploit these three factors to test hypotheses that challenge the conventional wisdom about the consumption and production choices of rural households and the behavior of markets in which they operate, whether they will provide new information in other words.

The challenge for the VDSA team is to ensure that the potential of the VDSA databases and infrastructure to deliver strong gains in economic and social welfare, including additions to scientific knowledge and capacity, are realized. There are some obvious research opportunities for the VDSA team and social scientists around the world. It is highly likely that the flow of benefits will be larger

13. These tables have been extracted from Bill & Melinda Gates Foundation annual reports and are likely to appear in future project proposals and reviews.

Table 8. Achievements of the VDSA Project in collecting and disseminating household survey data.

Activities	Targeted Outputs	Achievements
Gathering of longitudinal data on households, individuals and fields in 42 selected villages in years 1–6 of the project	Well-documented and edited high-quality data sets that can be downloaded from the project website or accessed from annual CDs distributed by the project	Completed household surveys and produced well-documented and validated high quality data sets: (i) five annual household-level data sets (2009/10 to 2013/14) for SAT India and Bangladesh villages and (ii) four annual household-level data (2010/11 to 2013/14) for East India for the full coverage of more than 40 households per village across 42 study villages in India and Bangladesh. Data collection for 2014–15 is on-going and to be completed on time. Completed Household Census in 2009 and 2014–15.
	Three annual household-level data sets for the full coverage of 40 (or more) households in 42 villages produced and disseminated.*	Household Survey data sets of 2009/10 to 2012/2013 have been released and available to users across the world through VDSA website (http://vdsa.icrisat.ac.in). Data for 2013/2014 will be released in 2015.
	Targeted outcome: (i) At least 200 scientists and development practitioners from the public and private sector use the data for understanding the dynamics of rural poverty in south Asia; (ii) Students from all over the world use this database for studying various research issues related to agricultural investments and household dynamics in rural economy	As of January 2015, 792 unique users from 39 countries of Asia, Africa, Europe and North America have downloaded newly released data. These include 366 students including 212 PhD students from about 150 universities/ institutes around the world. Use of the VDSA data sets by Asian students and researchers has increased rapidly in recent years.
Implementing punctual special-purpose surveys		Completed a special purpose surveys on (1) Gender, Food and Nutrition security; (2) Impact of MGNREGA; (3) Hybrid Rice in Bangladesh; (4) Groundwater Irrigation Markets in Bangladesh
Database development and management	Development of electronic version of the VLS data base with systematic and well defined documentation	The VDSA project has recently developed the VDSA Knowledge Bank with user-friendly data retrieval and on-line analytical processing features. It is the first of its kind in the CGIAR system and also the first in the world for the management of rural household survey data. Well documented databases are also available in Excel.
Website development and management	Information portal developed and hosted on the project website	Developed the VDSA web portal (http://vdsa.icrisat.ac.in). The VDSA Knowledge Bank is hosted on the server and linked to the VDSA website. Released well-documented and validated high quality household and meso-level data sets, and all publications during 1975-2014 including theses.

*These data sets correspond to agricultural years 1-3 of the project and will be available in years 3-5. Data sets for agricultural years 4 and 5 will be partially processed during the life of the project, but they will not be available for distribution in 5th year and in subsequent years after the project is completed.

Table 9. Achievements of the VDSA Project in collection and dissemination of Meso- level data.

Activities	Targeted Outputs	Achievements
Assembly of secondary agricultural meso-level data into an integrated database that is updated in time, expanded in coverage, extended in geographic area, and decentralized in the level of aggregation	• Data from different sources accumulated and compiled under an integrated, organized structure. • Two comprehensive revised data bases at the district level for India and Bangladesh. **Baseline:** Database for variables on land use, agricultural production, livestock, agro-climatic variables maintained for India till 1999.	• Developed two meso-(district, state/ region, sub-district) level databases for India (1966 to 2010) and Bangladesh (1952 to 2012). • Well-documented meso-level data have been released through the VDSA website (http://vdsa.icrisat.ac.in).
	Targeted outcome: • A total of 100 scientists and development practitioners use the data for making projections and establishing reference points for monitoring purposes • Students from all over the world use this database for research purposes • Ten technical reports on agricultural production and socio-economic indicators	• The Meso-level databases have attracted many institutes, students and scholars from India and foreign universities. The databases are being extensively used both within and outside ICRISAT. Users outside ICRISAT include institutes like Indian Council of Agricultural Research (ICAR), World Bank, World Food Program; lead research institutes and universities in India (CESS, NCAP, ISEC, etc.) and Bangladesh (BAU, BRRI, BARC, BARI, BSMARU, etc.); IRRI; CGIAR Research Programs (CRPs) on Policies, Institutes and Markets; Grain Legumes; Dryland Cereals; other CRPs and CGIAR institutes (CIMMYT, WorldFish). • A total of 792 researchers and students from 39 countries of the world including 366 students (out of which 212 are PhD students) have downloaded VDSA databases. Amongst these who have used meso-data are not known. • Data documentation manuals, flyers and poster on meso level data insight and coverage has been completed and printed. • Published 10 papers including 3 journal articles, 1 working paper, 4 conference papers and 2 research reports. These were on issues related to aggregate supply response, crop livestock typology, diversification of agriculture, change in cropping patterns, identifying target regions for technology dissemination, trends and growth rates, income and poverty, adoption of improved technology (HVCs, HYVs, crossbreeding, mechanization), tracking prices, wages and input costs; livestock density and feed availability; tracking consumption patterns (elasticity); role of infrastructure and road network on growth; market access and agricultural productivity.

Table 10. Achievements of the VDSA Project in analysis, publication and capacity building.

Activities	Targeted Outputs	Achievements
Implementation of in-house research projects for researchers directly involved in data collection	• Twenty research progress reports/ discussion papers from scientists in ICRISAT and its partner institutes • Five PhD dissertations guided by ICRISAT and its partners during the life of the project • Five journal articles by ICRISAT and its partners during the life of the project	• During May 2009–Dec 2014, the VDSA Project team has made 271 publications comprising journal articles (10), book chapter (1), doctoral dissertation (2), research bulletin (3), policy briefs (2), working papers (16), data documentation and training manuals (6), village profiles (8), conference papers/ proceedings (34), poster papers (10), village at a glance (30), workshop/ conference presentations (99), research reports (17) and internship reports (33). • Publications made by the global data users are not included here. • Provided VDSA Research Fellowships to eight Ph.D. students and three young researchers. Two scholars have successfully completed Doctoral Degrees. Others are in the process of submission of their dissertation.
Capacity Building through training, implementation of competitive grants and joint publications	• Fifteen research progress reports and discussion papers during the life of the project from regional agro-biological and social scientists who conduct special-purpose surveys in the selected villages. **Targeted Outcomes:** • Research capacity enhanced through interactions among senior and junior researchers both inside and outside the project	• Out of the total 271 publications under the VDSA project, 39 joint publications were with national scientists. • Following a competitive grants program, VDSA Research Fellowships were given to eight Ph.D. students and three young researchers. • Trained 524 researchers (scientists, field investigators and students) comprising of 154 female trainees. Amongst these, eight are Ph.D. students; one female Ph.D. student has completed her degree, two others are pursuing. • During May 2009 to December 2014, 57 students were trained as interns. The interns worked on various topics, using the VDSA micro- and meso-data, including performance of crop production in India, export competiveness of sorghum, sorghum producing areas, impact of Integrated Child Development scheme (ICDS), returns to education, impact of MGNREGA, household nutrition, women empowerment, labor issues, arbitrage opportunities of small-scale agricultural households and technology adoption. Students came from 15 universities/ institutes in India, USA, UK, Netherlands, New Zealand and Norway. These include Cornell University, University of Illinois, London School of Economics and Political Science, University of Oslo, University of Wisconsin, University of North Dakota, Delhi University, Gokhale Institute of Politics and Economics (GIPE), Achrya NG Ranga Agricultural University (ANGRAU). Three students were funded by World Food Prize Borlaug-Ruan International internship.

for research that exploits the cross section and time series nature of the data. These opportunities (reflecting my interests in production economics) include:

- Empirically testing new theories, such as the state contingent approach of Chambers and Quiggin (2000), about how economic agents make decisions under risk, an area of research where the original VLS project had a major impact;
- Using the data to estimate productivity growth in regions covered by the VDSA project and decomposing this productivity growth into components such as technical change and technical efficiency (following O'Donnell, 2010, 2011 and 2006). This gives insight into the potential role of research and extension services in promoting efficiency. The data have not previously been used to address these questions;
- Exploiting the panel nature of the data to continue research into how household nutrition and gender issues are influenced by variability in weather, markets and off-farm employment and constraints in factor markets;
- Continuing the work to develop representative farm models based partly on VDSA data that allow the impact of potential technologies and rural policies to be simulated;
- The villages still provide a research environment with a household perspective to trial technologies. This capacity is not being used to the extent it was under the VLS project but the opportunities are still there.
- The VDSA villages still provide the infrastructure for special purpose surveys and analyses including baseline data extending back to the 80s.

As in the past, much of the research program will be undertaken by scholars around the world. In reviewing the proposal for the present VDSA project in 2009, Rosenzweig observed:

"……, ICRISAT does not have a comparative advantage in analyzing data. Resources should be used not for intensive analyses at ICRISAT, but for data dissemination and for meetings that bring together ICRISAT and outside researchers using the data. This is not to say that ICRISAT researchers should not play important roles in data use, as this will help improve the design of the VLS, only that analysis should be seen as being carried out by the global research community, as was the case for the original VLS…."

I think Rosenzweig understated the potential of the VDSA team to undertake a substantial research program. However, the VDSA team plays an important role in making scholars and policy makers aware of the potential of the VDSA databases and infrastructure that extends far beyond the development of a database. Their achievements in holding conferences and symposia in India, described in Table 11, is important not only as a vehicle for presenting results of analysis but also as a vehicle for promoting awareness of the databases and infrastructure. Similarly, presenting papers at international conferences promotes awareness.

Perhaps future promotional activities should target universities and research institutions throughout the world that have strong capacities in areas such production economics and risk and uncertainty. There may be benefits for the VDSA team, especially in terms of capacity building, from seeking a formal alliance with one or more of these institutions to ensure that achieving the potentially high impact outcomes from the VDSA projects is not left to chance.

Table 11. Workshops/Symposia/Policy Dialogues.

Topic	Date and Venue	Key participants
Policy dialogue on 'Priorities and possibilities of investment for accelerating agricultural growth and reducing poverty in Odisha'	Bhubaneswar, India (Jul 6, 2013)	Principal Secretary, Govt. of Odisha state; Senior Secretary, Govt. of Odisha; Representatives from Dept of Agriculture, Rural Development, NGOs, Farmers cooperatives, etc.
Policy dialogue on 'Rural labor market and agriculture'	Hyderabad, India (Jan 17-18, 2013)	Representatives from labor organization, Farmers association, Govt. officials, NGOs, researchers, etc.
Workshop on 'Dynamics of rural livelihoods and poverty'	Hyderabad, India (Nov 5-6, 2013)	Gender and Nutrition specialists, Consultant of International Centre for Women, other 50 researchers.
National Symposium and Policy Dialogue on 'Dynamics of Rural Labour Markets: Implications for Agricultural Growth and Rural Transformation'	New Delhi, India (Sep 15-16, 2014)	Former minister, Govt. of India; Member, Planning Commission, Govt. of India; Secretary, Dept. of Agriculture, Govt. of India; researchers from national and international organizations.
Symposium on 'Transformation in rural economy and employment opportunities in Eastern India: Implications for inclusive growth'	Ranchi, Jharkhand state, India (Dec 17, 2014)	Former member, Planning Commission, Govt. of India; Secretaries from Govt. of Jharkhand, Bihar and West Bengal states; about 60 researchers from national and international organizations.

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15 Appendixes

15.1 History of the VLS and VDSA projects

Year	Comment
1975 – 1984	ICRISAT undertook the Village Level Studies data collection and analysis – Generation 1
1999	First Workshop on Village Level Studies (December 1st, 1999) – held in Zimbabwe; Objective was to draw interest from all VLS stakeholders globally and resurrect VLS activity in Asia and Africa; the output of this workshop was a draft proposal for VLS to include Asia and Africa - funded by ICRISAT core funds and US University Linkage Fund (USAID) in collaboration with Bob Evenson, Director of the Economics Growth Center, Yale University
2000/2001	First survey: funding from ODI and ICRISAT. ODI was interested to examine the changes in the VLS villages from earlier decades and learn about farmers' livelihood options for their overall strategic assessment using the Livelihoods Framework. This covered Aurepalle and Dokur. Report was published in collaboration with ODI who was involved in the study and publication write-up.
2002 to 2004	September 2002 – Bantilan presented the VLS proposal during the CGIAR Centers Week in Washington DC As above, funds from various ICRISAT activities that match work – Bantilan and KPC Rao started with Annual Survey, followed by Semestral Survey to cover the two seasons in 2004.
2004	Second Workshop on Village Level Studies on Sept 2004 – held in Patancheru. Objective was to address VLS Methodological Issues and Applications; for analysis of changes comparing the VLS generation 1 data (1975–1985) with the generation 2 data (2001-2004) VLS drew wider interest from World Bank and Oxford University (Stefan Dercon and Pramila Krishnan were actively involved in the workshop; Mark Rosenzweig of Harvard University and Takashi Kurosaki from Japan also participated actively). Other VLS scholars also participated actively. Second version of the proposal focused on methodology.
2005	Bantilan and KPC Rao decided to bite the bullet and go for high frequency VLS rounds to reflect the full set of modules of the VLS. As above, funds primarily came from the various ICRISAT activities that match work. A census was undertaken and a tracking survey was implemented to track the split households. Funding from World Bank Research Division (and Stefan Dercon of Oxford) Also co-funded through the Village Level Insurance surveys (KPC Rao and Kumar PhD thesis) funded by the World Bank
2006	Surveys continue with more stakeholders getting interested in the revival of the VLS. During this period, the activity was increasingly supported by European Community (EC) funds, which specifically identified support for Socioeconomics and Policy Program.

Year	Comment
2007	July 2007 - Bantilan and team sponsored a workshop on the VLS during the Annual American Agricultural Economics Conference held at Brown University (Bob Evenson, Hans Binswanger, Andy Foster, Mark Rosenzweig, Chris Udry and many more) – to discuss and follow-up Zimbabwe workshop revising the formal proposal.
2008	ICRISAT funding
	Bantilan presented a seminar at Cornell University upon invitation of Chris Barrett (Applied Economics Department Chairman and AAES Editor in Chief) and commences write-up of a CGIAR Challenge Program Proposal based on the Village Level Studies. The proposal deals primarily with the Agricultural Transformation Process and was known as the SMART Challenge Program Proposal
	Bantilan and team were invited by the Guelph University - Canadian team of social scientists from various Canadian Universities sponsored “Village Level Studies collaboration with Canada” led by Harry Cummings – funded by IDRC and supported by Caroline Pestieau, former Vice President at IDRC and ICRISAT Board Member
2009	Secured funding from Bill & Melinda Gates Foundation for a Scoping Study on the Village Level Studies – to cover Asia and Africa
2009/2010	Bill & Melinda Gates Foundation five year project funding
2010/2011	Bill & Melinda Gates Foundation five year project funding
2011/2012	Bill & Melinda Gates Foundation five year project funding
2012/2013	Bill & Melinda Gates Foundation five year project funding
2013/2014	Bill & Melinda Gates Foundation five year project funding
2014/2015	Note cost extension approved in 2012 due to the delay of implementation and MOUs with partners during year 1

CGIAR: Centers for Global International Agricultural Research

ICRISAT: International Center for Crop Research in the Semi-Arid Tropics

ODI: Overseas Development Institute

USAID: United States Agency for International Development

VLS: Village level studies

15.2 Accelerated technology trials in VLS villages (1979–80 to 2013–14)

Research area	Cropping year	Principal Investigator and research program	Villages tested	Type of research	Major findings
1. Testing improved watershed technology options	1979–80 to 1980–81	Farming systems research	Aurepalle Kanzara	Testing of watershed technologies with a few component plot trails	Beds and furrow not economically superior to flat cultivation. Comparative performance of the improved watershed technology was better in 1980–1981, but the mean net profits were low in both the improved and traditional systems
2. Diagnostic research on constraints to stand establishment	1981–82 1982–83	Pearl millet and sorghum physiology	Aurepalle	1. Farmer survey and observational measurement in 40 farmer's fields.	Farmer's seed samples had more than 70% germination in standard tests. Farmer seeding rates much higher than recommended but stands less than 50% recommended, less than 30% seeds sown emerge.
					Correct sowing depth contributes to better emergence but other environmental factors studied did not significantly affect emergence.
				2. Replicated trials on farmer's fields to see the effects of seed treatment, sowing depth, sowing date, and tillage on emergence.	Seed treatment beneficial.
					Inconclusive as control of depth was not precise with bullock drawn seed drill. No main effects, field by date interaction significant.
					Plowing significantly improved emergence
3. Pigeonpea rhizobium inoculation	1981–82 1982–83	Pulse microbiology	Aurepalle	Replicated trials in five farmers' fields with rhizobium inoculation with ICP1.	No response to rhizobium inoculation either in grain or total dry matter yields.
				Replication trials in six farmer's fields	Results suggested that the tested inoculum strain was inferior to local strains in the absence of fertilizer, neither the introduced nor local strains are fixing all N needed by this plant. So, N application is beneficial, P + Mo enhanced plant growth

Research area	Cropping year	Principal Investigator and research program	Villages tested	Type of research	Major findings
4. Striga resistant varieties	1983–84 1984–85	Sorghum breeding	Aurepalle, Kanzara, Shirapur	Replicated trial in sorghum sick field under farmer's management	Moderate to heavy striga in 1983–1984. Striga resistant cultivars SAR 1 & 2 had heavier grain yields than check CSH 1. Striga nil in SAR 1 & 2.and 140–160 striga plants for square meter in CSH 1. Little striga infestation in 1984–1985.
5. Rates of N-P-K in intercropping systems	1983–84 1984–85	Soil fertility and chemistry Farming systems research	Aurepalle	Large replicated trial in farmer's field. Improved pigeonpea cultivars in both years and improved cereal varieties in 1984–1985.	Most economic dose in 1983–1984 when rainfall was low but evenly distributed was 80 N and 60 P2 O5/ha. Higher N application on the cereals depressed pigeonpea grain and dry matter yields
6. Pigeonpea varieties with *heliothis* resistant characteristics in traditional intercropping systems.	1983–84 1984–85	Pulse Entomology	Aurepalle	Replicated trials in five farmers' fields each year	Poor stand establishment in pigeonpea prevented the detection of measurable differences in grain yields. However, cv. 1903 had significantly less pod borer damage than neighboring local varieties in the fertilizer trial described above.
7. Introduction of Hybrid pigeonpea (ICPH 2671)	2008–09	Pigeonpea Breeding	Aurepalle, Kanzara, Kinkheda, Kapanimbargi, Markabbinahalli	On 30 Farmers' fields	Performance was poor due to delayed sowing, excess rain in mid season and drought after sowing and at harvest time
8. Introduction of ICRISAT Sorghum Variety SPV 351	1983	Sorghum Breeding	Kanzara	On-farm Trials in farmers' fields	
9. Introduction of ICRISAT Sorghum Hybrid SPH 221	1984	Sorghum Breeding	Kanzara	On-farm Trials in farmers' fields	

Research area	Cropping year	Principal Investigator and research program	Villages tested	Type of research	Major findings
10. Field trials of Chickpea varieties ICCC 13, ICCC4,	1984	Chickpea Breeding	Kanzara	On-farm Trials in farmers' fields	
11. Demonstration of ICRISAT Pigeonpea Varieties ICPL 270, ICPL 292, ICPL 95 on farmer's field.	1984	Pigeonpea Breeding	Kanzara	On-farm Trials in farmers' fields	
12.Testing ICRISAT Chickpea variety ICCC 32	1985	Pigeonpea Breeding	Kanzara	On-farm Trials in farmers' fields	
13.Testing of ICRISAT Groundnut varieties ICGS-5, ICGS FDRS-4, ICGS FDRS-10 on farmer's field	1985	Groundnut Breeding	Kanzara	On-farm Trials in farmers' fields	
14. Introduction of ICRISAT Chickpea cultivars ICCV 2, ICCC 37, ICCC 42 on farmer's field.	1986	Chickpea Breeding	Kanzara	On-farm Trials in farmers' fields	
15. Introduction of ICRISAT Short duration Pigeonpea ICPL 87, ICPL 151	1987-90	Pigeonpea Breeding	Aurepalle, Kanzara, Shirapur	On-farm Trials in farmers' fields	

Research area	Cropping year	Principal Investigator and research program	Villages tested	Type of research	Major findings
16. Introduction of ICRISAT Medium duration, wilt resistance Pigeonpea ICP 8863	1987	Pigeonpea breeding	Aurepalle, Kanzara, Shirapur	On-farm Trials in farmers' fields	
17. Introduction of ICRISAT Sorghum Variety SPV 475	1988	Sorghum Breeding	Aurepalle, Kanzara, Shirapur	On-farm Trials in farmer's fields	
18. Introduction of ICRISAT Sorghum Hybrid SPH 296	1988	Sorghum Breeding	Aurepalle, Kanzara	On-farm Trials in farmer's fields	
19. Introduction of ICRISAT Medium duration, wilt and SM resistance Pigeonpea ICPL-87119 also known as Asha	1989	Pigeonpea breeding	Aurepalle, Kanzara, Kinkheda	On-farm Trials in farmer's fields	
20. Introduction of ICRISAT Sorghum Hybrid SPH 468	1993	Sorghum Breeding	Kanzara	On-farm Trials in farmer's fields	
21. Introduction of ICRISAT Chickpea Kabuli Variety JGK-1	2003	Chickpea Breeding	Kanzara	On-farm Trials in farmer's fields	

Research area	Cropping year	Principal Investigator and research program	Villages tested	Type of research	Major findings
22. Field trials of World first Hybrid Pigeon-pea ICPH 2671	2008-09	Pigeonpea breeding	Kanzara	On-farm Trials in 50 farmer's fields	
23. Field trials of ICPH 8, ICPH 2671 and ICPH 2740	2010-11	Pigeonpea breeding	All 18 VDSA Villages (Aurepalle, Kanzara, Kinkheda, Shirapur, Kalman, Kapanimbargi and Markabbinahalli etc.)	On-farm testing and test marketing.	First commercial pigeonpea hybrid. Trials have revealed that there was no difference in taste in hybrids. The hybrid was 35% superior over the best variety at Akola villages.
24. Field trials of ICPH 2671 and ICPH 2740	2013-14	Pigeonpea breeding	Aurepalle, Dokur, Kanzara, Kapanimbargi, Markabbinahalli, Tharati and Bellagdamadugu Village	On farm testing and test marketing.	Except in Kanzara village, other study villages in Andhra Pradesh and Karnataka not performed very well comparatively with existing pigeonpea varieties. Pigeonpea hybrids have demonstrated 30% yield advantage in farmers' fields in Akola district villages.
25. Field trials of drought tolerant Groundnut variety of ICGV 9114, ICGV 0350	2010-11	Groundnut breeding	Belladamadugu, Tharati, Kapanimbargi, Aurepalle and Dokur	On-farm testing trials	Another drought tolerant groundnut variety and gaining popularity and it spreads to different farmers.
26. Field trials of drought tolerant Groundnut variety of ICGV 9114, ICGV 0350	2013-14	Groundnut breeding	Aurepalle, Dokur,	On-farm testing trials	Performed well on par with the local varieties.

15.3 VLS/VDSA peer reviewed publications by research area

Risk uncertainty and insurance

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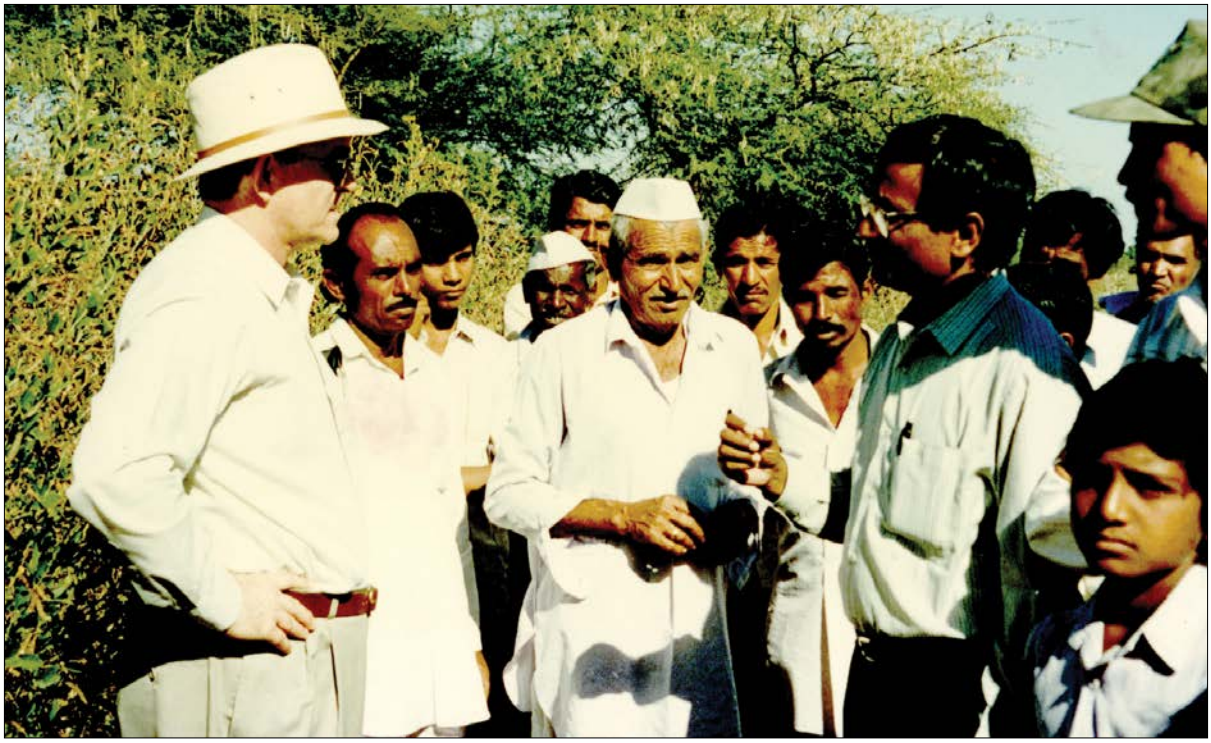

Dr Jim Ryan with the farmers of Kanzara village.

VDSA Project Launching Meeting 2009.

Participants of the VDSA Annual Review Meeting.

VDSA Annual Review Meeting 2013.

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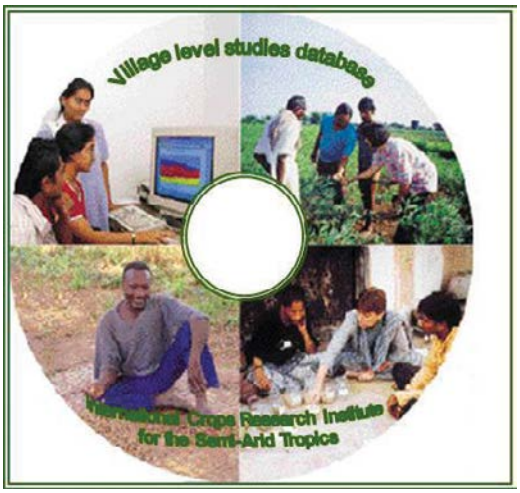
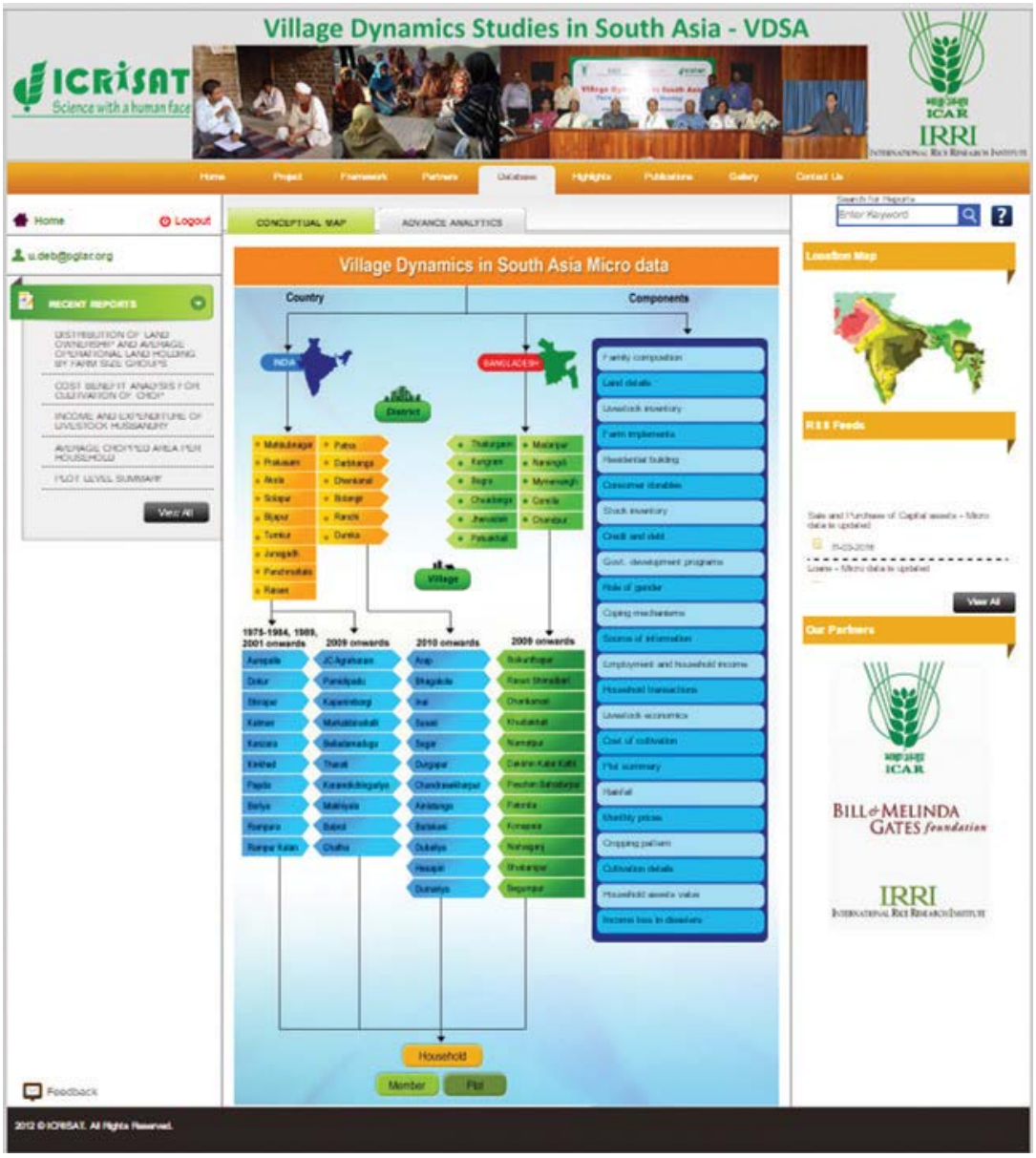
Field Investigator is interviewing a farmer.

Mainframe computer used for data entry of the VLS (1975).

VDSA Data Bank



Data distributed through CD.



VDSA Knowledge Bank (http://vdsakb.icrisat.ac.in).

VDSA Website ((http://vdsa.icrisat.ac.in)

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We work across the entire value chain from developing new varieties to agri-business and linking farmers to markets.

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