Sachin Chaturvedi · Krishna Ravi Srinivas
Editors

Socio-Economic Impact Assessment of Genetically Modified Crops

Global Implications Based on Case-Studies from India

Springer

Socio-Economic Impact Assessment of Genetically Modified Crops

"Interesting times, like these, that are witness to 'Kisan Satyagraha' demanding freedom to leverage technologies simultaneously with concerns on their safety and utility call for imaginative solutions for growth and equity in the largest-employing agriculture sector. The product of painstaking research undertaken by Research and Information Systems for Developing Countries (RIS), New Delhi and edited by two of the leading scholars in the area, this book addresses this issue with empirical evidence from a sample of 1500 farm households growing different crops across several states.

It gives a glimpse into a robust inter-disciplinary socio-economic assessment framework that includes cost-benefit analysis with qualitative participatory approaches and choice-based experiments in India's regionally diverse milieu. Importantly, it argues for factoring in the perceptions of the prospective adopting farmers on the utility, risks, and rewards of the technologies involved. The findings have solemn implications for application, evaluation, commercialisation, and monitoring of biotechnologies in line with Article 26.1 of the Cartagena Protocol in developing countries like India. This is a must-read for all those involved in developing, utilising, and regulating biotechnologies as well as those interested in reviving agriculture and enhancing farmers' incomes."

—N. Chandrasekhara Rao, Ph.D. *(Development Studies) Professor Institute of Economic Growth University of Delhi Enclave, North Campus New Delhi-110 007*

"This new volume—*Socio-Economic Impact Assessment of Genetically Modified Crops—Global Implications Based on Case-Studies from India* is a major accomplishment. Unlike much of the literature in this critical field, it focuses on field work, data analysis, and methodologies—in each case treating implementation as a central concern. Most important, it signals the future utility and ventures into the future of biotech, already rapidly developing around the world: gene editing. It should be an important resource for public policy analysts, scholars and practitioners alike."

—Ronald J. Herring, *Professor of Government, Emeritus, College of Arts and Sciences, Visiting International Professor of Agriculture and Rural Development, College of Agriculture and Life Sciences, Fellow, Atkinson Center for a Sustainable Future, Cornell University, White Hall 117, Ithaca, NY, USA 14853*

"Article 26.1 of the Cartagena Protocol on Biosafety (CPB) states: "The Parties, in reaching a decision on import under this Protocol or under its domestic measures implementing the Protocol, may take into account, consistent with their international obligations, socioeconomic considerations arising from the impact of living modified organisms on the conservation and sustainable use of biological diversity, especially with regard to the value of biological diversity to indigenous and local communities."

There are polarised opinions for and against the possibility of including socio-economic considerations in regulatory approval processes and decision making for genetically modified products in addition to scientific food and environmental risk assessment protocols. Many countries have provisions for SECs in their biotechnology/ biosafety regimes although such provisions are divergent and implementation is erratic. European countries prefer a comprehensive approach and most of the other countries have opted for an approach that is related to scientific risk analysis and limit scope of SEC.

The Ministry of Environment, Forests and Climate Change (MoEFCC) under the Biosafety Capacity Building Project, Phase II (2011–2015) commissioned a research project on Socio Economic Considerations under Article 26.1 of CPB with specific mandates on developing methodologies for Socio-Economic Assessment, Methodology for Cost-Benefit Analysis and Guidance Document. RIS was identified as the co-ordinating agency with six partner institutions.

This book edited by Sachin Chaturvedi, Krishna Ravi Srinivas *Socio-Economic Impact Assessment of Genetically Modified Crops—Global Implications Based on Case-Studies from India* is largely an outcome the above mentioned project including certain latest data and experiences in addressing the issue. As resource person of the projects implemented it should be emphasized that each of the article written by various authors in this volume is based on a thorough qualitative and quantitative analysis of both primary and secondary data from real ground situation. In addition, the analysis and discussions embodied in these articles is enriched by brain storming sessions with resource persons across disciplines and stakeholders consultations including farmers, consumers, industry and policy makers taking into account international literature and developments in the subject.

While the Adhoc group set by Cartagena Secretariat is yet conclude its recommendations on the formulation of methods and protocols for assessment of social-economics assessment of LMOs, this volume could serve as a significant narrative in the discourse on the evolution of international framework for the socio economic assessment LMOs particularly genetically engineered crops.

Since Bt cotton with two insect resistant genes is only approved for cultivation in India, most of the authors refer to the decade of experiences and data in their chapters. Some have documented ex-ante studies of herbicide tolerant corn and insect resistant Brinjal. Based on the information in chapters and their own research finding the editors attempted to author Chapter 11 on Frameworks and Guidelines for Socio-Economic Assessment suggesting the importance in bringing together economic factors and non-economic factors beyond the cost benefit analysis. In Chapter 12 the importance of far reaching consequences in application genome editing and gene drives in terms of ethical, legal and regulatory challenges was also recognised for future work. The message is very clear. A careful analysis of the range of parameters related to technology and application along the value chain from research to the commercial utilisation need to be investigated in terms of safety, effectiveness, social and economic factors for increased adoption and long term environmental and socio-economic sustainability of products of both genetic engineering of the past and emerging technologies. Such assessment should consider local, regional and sub-regional specialities and address problems of small and medium farmers for sustainable agricultural productivity. There cannot be one solution for all situations. Therefore, case-by-case assessment considering crop, traits, markets and local needs is emphasised for a better impact on ecological and economic sustainability and food security.

Over the next 30 years, the global human population is expected to grow by 25% and reach 10 billion and accordingly the demand for food, fodder, energy and diversity in food consumption. To meet these challenges, agricultural crop and animal improvements require accelerated application of emerging technologies such as genotyping, marker-assisted selection, high-throughput phenotyping, genome editing, genomic selection and de novo domestication using speed breeding to enable plant breeders to keep pace with a changing environment and socio-economic equations of the times. In this context, this volume would serve as primer and template for future work on the topic."

—S. R. Rao, *Former Senior Adviser, Department of Biotechnology,*
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Foreword

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सदस्य
Prof. Ramesh Chand
MEMBER

सत्यमेव जयते

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The importance of biotechnology in agriculture is too obvious to be stated. While Bt cotton in India is a good example of successful adoption of a product of biotechnology, the challenge lies in developing biotech crops that meet multiple objectives and are acceptable to all sections of society. There has been a long debate over genetically modified crops, particularly food crops, in India and almost the entire world. The proponents cite protection from insects and pests resulting in higher harvest, lower use of agrochemicals considered to have an adverse effect on human, livestock and ecosystem, cost-effective weed control and quality traits as well established benefits from GM technology, whereas dangers of fiddling with the nature, environmental impacts in the long run, allergies, health impacts, seed prices and unknown consequences are cited as negative impacts of GM crops by the opponents. While many studies and meta-analyses have clearly demonstrated the economic gains, increase in productivity and increase in farmers' welfare, these alone are not sufficient to instil full confidence and greater acceptability. Socio-Economic Assessment, that is credible and comprehensive, is necessary for decision-making. It will enable decision-makers, particularly regulators, to make informed decisions and to understand better the impacts of GMOs, instead of focusing on one impact/aspect.

The Cartagena Protocol on Biosafety through Article 26.1 enables incorporating socio-economic considerations in decision-making. Globally, this has been implemented by many countries although there is no consensus on what the key elements are that have to be taken into account for socio-economic considerations. The work of the Ad Hoc Technical Expert Group has identified some key elements and has come up with suggestions.

It is heartening to know that under a UNEP/GEF-funded project, implemented by the Ministry of Environment, Forests and Climate Change (MoEF&CC), Government of India, RIS with six partner institutions has undertaken a research project to develop Framework Guidelines and Methodologies for Socio-Economic Assessment of biotechnology and GM products. In this, it is interesting to know that some field studies have been undertaken on biotech crops other than Bt cotton and on various traits, based on the trials/experiments, in different stages. The data from the fieldwork and their analysis show that farmers have huge expectations from GM crops and are willing to pay more for such crops with desired traits provided they yield higher income. At the same time, farmers and other stakeholders have shared their perceptions on biosafety, risks and expectations from GM crops as well as environmental and health impact. These are important for regulation on biotechnology and policy on biotech crops and biotechnology.

Similarly, the Framework Guidelines and Methodologies developed by RIS and published in this volume are quite relevant and useful for undertaking Socio-Economic Assessment. As RIS has prepared these guidelines with insights from case studies, survey of literature and research, they are an excellent blend of perspectives from theory and praxis. Since these are certainly adoptable/adaptable in different situations, the findings from this volume are relevant to other countries as well.

Further, the volume envisages the role and relevance of socio-economic considerations and Socio-Economic Assessment of living modified organisms and emerging technologies like Gene drive, genome-edited crops and GM mosquitoes. This is a highly complex field, and obviously, more work is needed on various aspects of GM organisms and technologies, but through this timely volume, a valuable beginning has been made.

I consider this as an important contribution from India to the global debate and policy-making on GM products and crops. I congratulate RIS, the partner institutions and MoEF&CC and the authors of various chapters for taking up this project and for publication of this volume. This volume will surely help in taking the discourse and policy on GM crops forward.

July 2019

Ramesh Chand
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Preface

Governance of new and emerging technologies is becoming more challenging and complex than ever before, partly on account of rapid advancements in technology and their diffusion. Convergence of technologies is another challenge, this has resulted in new ideas like anticipatory governance and more emphasis on public engagement, and new paradigms like responsible research and governance have also been suggested. A key issue in these debates is the role of ethics in technology governance. Can we think in terms of global ethics for S&T governance or should we accept that diversity in ethics is inevitable and hence non-Western perspectives should be given equal importance?[1] Our view is that some of the models and approaches developed or proposed from developing countries need a serious consideration in technology governance. They may bring in dimensions that are relevant to developing countries and also to developed countries. Experience should inform theory-making, and there is much to learn from the experiences of the developing world in applying and adopting Science and Technology and Innovation (S&T and I) for national development and socio-economic advancement. This is relevant to developing governance regimes for emerging technologies also, and as we have pointed out that, even in developed countries, the limitations of ELSI are acknowledged. Similarly, the issue of ethics also cannot be addressed solely from Western ideas on ethics or justice or fairness. Instead, we need to link ethics with more relevant ideas. Taking this into account, the concept of Access, Equity and Inclusion (AEI) has been put forth by us (Chaturvedi, Srinivas and Rastogi, 2015). Instead of trying to discuss this in terms of just ideas, we have tried to think in terms of indicators and measuring them.

Two implications follow from this; the first is AEI goes beyond abstract idea of ethics and links ethics with outcomes, and the second is such an exercise should result in verifiable and quantifiable indicators. Regarding governance of emerging technologies, we can take this to mean that we will assess their impacts in terms of Access, Equity and Inclusion. For example, we can assess the impacts of genome-edited crops or synthetic biology on the basis of the question, as to whether

[1]See Ladikas, et al. 2015.

the adoption results in better access, or, are the gains equitably distributed or whether the technology is inclusive enough of use and adoption by a wide range of producers and consumers. This question can be part of any Socio-Economic Assessment.

Even as countries and regulators grapple with these issues, we need to remember that some of these concerns were raised in the early years of biotechnology regulation when scientists met in Asimolar and came up with a Asimolar declaration. At that time, their concern was limited to biosafety and biosecurity and on how to regulate inter alia laboratory experiments in the absence of regulation. Socio-economic impacts were not in their agenda, but as it became clear that biotechnology regulation would result in more challenges for regulation, issues related to Ethical, Legal and Social Implications (ELSI) were made part of the research supported by governments in USA and UK, while traditional technology assessments (TA), foresight studies and economic analysis of impacts were continued to support. But today, we know that ELSI is necessary but may not be sufficient in case of emerging technologies. As pointed out in the earlier paragraph, AEI framework can be used to go beyond ELSI approach.

Ever since the adoption of genetically modified (GM) crops in 1994 by USA, followed by Canada, Argentina, Uruguay and Australia in the next few years, the diffusion of GM crops and their impacts has been studied extensively. The diffusion of GM crops has been geographically uneven with most countries in Africa and Europe not opting for their cultivation for one reason or another. But in Latin America and Asia, the response has been better. Some countries do not permit cultivation but allow import of GM grains for use as feed, and some countries limit cultivation to few crops but allow import of many varieties of GM grains. The transatlantic divide on adoption of GM crops had resulted in a dispute before WTO with mixed outcomes. After two decades and half of introduction of GM crops, it can be said that their adoption has been fast, and despite controversies and setbacks, GM crops are set to be introduced in more countries and in many crops. But today, the world is moving beyond GM crops, and new plant breeding techniques are supplementing technologies associated with development and adoption of GM crops. The biotechnology revolution in agriculture is a sequel to Green Revolution. But with more powerful and sophisticated plant breeding technologies on the anvil, questions relating to their economic benefits and environmental impacts are inevitable. Over the years, the regulatory regimes and policies have tried to address these concerns and respond to concerns of stakeholders on safety of GM foods. But from a developing country perspective, the development dimension is equally important and hence what is the role of GM crops in addressing food security and alleviation of hunger are important.

In the last two decades or so, many initiatives have been taken by, inter alia, FAO and UNEP on building capacity in developing countries and LDCs on biosafety regimes and in regulatory capacity in biotechnology. This has enabled to establish/enhance the capacity in biosafety and biotechnology. Obviously as CPB has been ratified by almost all the developing countries and LDCs, implementing provisions of CPB has benefitted much from capacity building exercises and guidance provided by international agencies. India was a strong supporter for forming CPB and had ratified CPB. It was among the first few countries in developing world to establish a separate Department for Biotechnology, i.e. Department of Biotechnology in 1986. Further as early as 1989, it had formulated the rules for regulating biotechnology products under Environmental Protection Act 1986. Over the years, India had gained experience in regulating biotechnology products in different sectors. The first GM crop, Bt cotton, was approved for commercial cultivation in 2002.

In India, the Ministry for Environment, Forests and Climate Change (MoEFCC) is the nodal ministry for CBD/CPB. It is also an important agency in biotechnology regulation as Genetic Engineering Advisory Committee (GEAC) function under the auspices of MoEFCC. MoEFCC is active in capacity building in biosafety. MoEFCC is deeply engaged in the CPB process, and India has contributed significantly in debates and discussions on CPB in various Conference of Parties (COPs). MOEFCC, being the nodal ministry for CBD, is engaged in implementing Article 26.1 and in the global discussions on Article 26.1. The Ministry of Environment, Forests and Climate Change (MoEFCC) under the Biosafety Capacity Building Project, Phase II, funded by UNEP/GEF, decided to fund and support a research project on Socio-Economic Considerations under Article 26.1 of CPB with specific mandates on developing methodologies for Socio-Economic Assessment, Methodology for Cost-Benefit Analysis and Guidance Document. Research and Information System for Developing Countries (RIS) was identified as the co-ordinating agency for this research project. RIS is a policy research think tank with Ministry of External Affairs, Government of India.

RIS has been concerned and working on agricultural biotechnology and development issues, since the late eighties, and analysed the developments from a developing country perspective. As part of this, RIS has researched on Cartagena Protocol on Biosafety (CPB). RIS has been conducting research on CBD, CPB and biotechnology regulation for more than two decades. It has worked with Secretariat of CBD/CPB, MoEFCC and Department of Biotechnology (DBT), Government of India, on Socio-Economic Assessment of LMOs and has participated in Conference of Parties/Meeting of Parties of CBD/CPB, contributed to workshops organised by CBD and MoEFCC besides taking part in online discussions organised by CBD Secretariat. The research from RIS in this issue has resulted in journal articles, inputs to CBD Secretariat and Policy Briefs and a special issue of Asian Biotechnology and Development Review (ABDR), Vol. 14 No. 3 November 2012 http://www.ris.org.in/journals-n-newsletters/Asian-Biotechnology-Development-Review.

With the support of MOEFCC and opinions from external experts, six institutions were identified as partner institutions. They were:

- Gujarat Institute of Development Research (GIDR), Gandhinagar, Gujarat,
- Indian Agricultural Research Institute (IARI), New Delhi,
- National Academy of Agricultural Research Management (NAARM), Hyderabad,

- Institute for Socio-Economic Change (ISEC), Bangalore,
- Tamil Nadu Agricultural University (TNAU), Coimbatore and
- University of Agricultural Sciences (UAS), Raichur, Karnataka.

IARI and NAARM are research institutes under Indian Council for Agricultural Research (ICAR). GIDR and ISEC are research centres recognised and supported by Indian Council for Social Science Research (ICSSR). TNAU and UAS are state agricultural universities, recognised and supported by ICAR. The experts consulted were from inter alia, Department of Biotechnology, University of Hyderabad, ICAR, Institute of Economic Growth, Center for Development Studies (Thiruvananthapuram) and ISEC.

The project envisaged that RIS in consultation with partner institutions and other experts would produce a set of deliverables, viz. a guidance document, a model questionnaire and methodologies for SE assessment and methodology for cost–benefit analysis. The questionnaires were to be developed in consultation with experts and institutions. They were to be revised after being tested with data collection in the field. The draft questionnaire was initially developed after rounds of discussions with experts and institutions. Subsequently, it was tested in the field, and based on the response from stakeholders and experience in data collection, it was revised. The revised questionnaire was used in the project for data collection. Minor modifications were made to make it more relevant to the region. It was also translated into regional languages and used for data collection.

Based on the information provided by MoEF&CC on crops and traits approved for conducting research and field trials, each institution had identified two crops and two traits for field survey and research. It was envisaged that some institutions which would collect data on a LMO with a specific trait. Information about stakeholders' expectations on GM crops and willingness to pay for future LMOs with specific traits was collected through the questionnaire.

The principal investigators in the institutions chose the most relevant crops and traits, in consultation with their colleagues, taking into account the crops cultivated in the respective states/area to be covered by fieldwork and relevant socio-economic factors. It was decided to include Bt cotton as the experience of the farmers on cultivating Bt cotton, and their perceptions on Bt cotton were very important for a study on SE assessment of LMOs. As the scope of the project was restricted to LMOs with single trait, stacking of genes and combining traits in a LMO were not considered. Moreover, from the pipeline survey, traits are likely to be commercialised earlier or have undergone/undergoing field trials been given preference for assessing their socio-economic impacts.

Based on the field survey and research by RIS, reports were prepared and submitted to MoEF&CC. On the basis of these reports, MoEF&CC published a resource document "Report on Guidelines and Methodologies for Socio-Economic Assessment of LMOs". This volume which builds upon on the report, has been produced with the subsequent research and is based on the revised and expanded reports from the six institutions.

In the literature on CPB and implementing Article 26.1, this is a unique volume that draws on insights from field surveys and research on CPB and implementation of Article 26.1 to develop Guidelines and Methodologies for Socio-Economic Assessment (SEA). It is hoped that the guidelines and methodologies will be useful in doing SEA and taking into account SEC in decision-making,

Obviously, this cannot be the final word or the only possible set of guidelines and methodologies, and certainly, there is much more to be done. As Parties to CBD are engaged with developments like synthetic biology, Gene drive, etc., there is a need to expand the work on SEA to them as well and see whether the guidelines and methodologies along with current regulations for LMOs/GMOs can be adopted for governing them. We hope that this volume can contribute to that as well.

We would like to express our sincere gratitude to all the contributors and experts for their contributions and for making this volume possible. It was our pleasure working with them during the project and after that for publishing this volume.

We are grateful to the Ministry of Environment, Forests and Climate Change (MoEF&CC), Government of India, for selecting RIS to undertake the project on "Guidelines and Methodologies for Socio-Economic Assessment" under the UNEP/GEF Capacity Building Project on Biosafety and for permitting us to publish this volume based on the research under the project. We thank Shri. Hem Pande the then Additional Secretary, Ministry of Environment & Forests for his support to the project and to RIS in the project. We thank the then Secretary, MoEF&CC, Shri. Ajay Narayan Jha, and Smt. Dr. Amita Prasad for their support and for publishing the "Resource Document on Socio-Economic Considerations (SECs) of Living Modified Organisms (LMOs)", a publication from the project. This volume draws on this resource document as a key resource, and we have used it in writing this volume.

Dr. Ranjini Warrier (Former Advisor and National Project Co-ordinator of UNEP/GEF Capacity Building Project on Biosafety at MoEF&CC and former Co-Chair, AHTEG on SECs, CBD) has been a great source of support and guidance. We are grateful to her for the same.

We have benefitted immensely from the advice and expert opinions of Dr. S. R. Rao (Former Advisor, DBT), Prof. Manmohan Agarwal (RBI Chair Professor, Centre for Development Studies, Thiruvananthapuram), Prof. P. G. Chengappa (Former ICAR National Professor, Institute for Social and Economic Change, Bangalore, and Former VC, UAS, Dharwad), Prof. E. Haribabu (Former Professor and Pro-VC, Central University of Hyderabad), Dr. T. P Rajendran (Former, ADG, ICAR) and Prof. N. Chandrasekhara Rao (Professor, Institute of Economic Growth, New Delhi), and we thank them for their time and opinions.

We are grateful to Dr. Vibha Ahuja, Chief General Manager, BCIL, and the Project Co-ordination Unit, BCIL, for support and for co-ordinating the project. We thank Dr. Murali Krishna, MoEF&CC, for his support and smooth handling of the project.

We thank Mr. M. C. Arora and his team in RIS for the administrative support. Dr. Nimita Pandey prepared the list of tables and figures and also worked on references for few chapters. We thank her for the same.

At Springer, Ms. Nupoor Singh took an active interest in this publication project and helped us in understanding and completing the publication process while Mr. Ramesh Kumaran co-ordinated the publication project and handled the contents. We thank Ms. Jayanthi Narayanaswamy for co-ordinating the production and completion of publication process at Springer and for ensuring that the publication time line was adhered to. We thank them for their professional support and interest shown in the project.

The views and opinions expressed in this volume need not be construed as views and opinions of UNEP/GEF or of MoEF&CC or of Ministry of External Affairs or of the institutions to which the contributors are associated with, including RIS. The usual disclaimers apply.

New Delhi, India

Sachin Chaturvedi
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Contents

About the Editors

Prof. Sachin Chaturvedi is Director General at the Research and Information System for Developing Countries (RIS), a New Delhi-based think tank. He was a Global Justice Fellow at the MacMillan Center for International Affairs at Yale University. His work currently focuses on issues related to development economics, development finance, SDGs, and South–South Cooperation. He has also worked on trade, investment, and innovation linkages with a special focus on the WTO. He has authored/edited 10 books, contributed chapters in various edited volumes and published several research articles in a number of prestigious journals. He has served as a Visiting Professor at Jawaharlal Nehru University (JNU), a Developing Country Fellow at the University of Amsterdam (1996), a Visiting Fellow at the Institute of Advanced Studies, Shimla (2003), and a Visiting Scholar at the German Development Institute (2007). He is a Member of the Reserve Bank of India's (RBI) Central Board of Directors. He has been writing on biotechnology and development issues since the early 1990s and has led research projects on biotechnology and development issues, e.g. for UNESCO, FAO, Department of Biotechnology, and the MOEF&CC.

Krishna Ravi Srinivas holds a Ph.D. from the National Law School University of India, Bangalore. He has been a Fulbright Fellow (Visiting Scholar) at the University of Pennsylvania, a Visiting Scholar at the Law School, Indiana University, Bloomington, and a Postdoctoral Research Fellow at the South Centre, Geneva. He has taught at the IIM-B as a Visiting Faculty. For his Ph.D., he conducted research on agricultural biodiversity and intellectual property rights. He has published extensively on intellectual property rights, traditional knowledge, open source, open innovation, commons and climate change, IPRs, and technology transfer. He is currently a Consultant to the Research and Information System for

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List of Figures

List of Tables

Part I
Introduction

Chapter 1
Cartagena Protocol, Socio-Economic Assessment, and Literature Review of Socio-Economic Assessment (SEA) Studies in India

Sachin Chaturvedi, Krishna Ravi Srinivas and Amit Kumar

Abstract This chapter provides an overview of the origins of the Cartagena Protocol on Biosafety (CPB), the relevant provisions on Socio-Economic Assessment of LMOs and literature review of socio-economic assessment studies in India. It describes how Article 26.1 has been interpreted and implemented. It analyses the developments in CBD and CPB on interpreting Article 26.1 and the work of Ad hoc Technical Experts Working Group (AHTEG). The linkage between CPB and other international treaties and conventions is also examined and it is pointed out that Article 26.1 has been interpreted and implemented in a manner that is consistent with obligations under other treaties/conventions. The literature review on assessing the socio-economic impacts of GMOs in India shows that most of the studies focussed on economic aspects but this was not unique to India. On the other hand the diversity in methodologies used in them and the findings show that there is scope for future work on socio-economic impacts in India and elsewhere. Thus in future more action in terms of theory and practice are required in understanding socio-economic impacts by undertaking studies and by interpreting and implementing Article 26.1. Both exercises can create a synergy that can be helpful in realizing the objectives of Article 26.1 of CPB.

Keywords CPB · AHTEG · Socio-economic impacts · Article 26.1 · COP-MOP

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1.1 Introduction

The Cartagena Protocol on Biosafety (CPB) is a protocol negotiated, and ratified under the Convention on Biological Diversity (CBD). As it is a protocol under CBD, its objectives are in alignment with that of CBD and hence impacts of products of biotechnology on environment are a major concern in CPB. CPB defines and its provisions deal with Living Modified Organisms, particularly their impacts on environment, movement of LMO across countries and handling LMO when they are produced in one country and are meant to be use in another country/countries. In the literature, often it is used as a synonym for Genetically Modified Organisms (GMO). CPB in Article3, defines LMO as "*g) 'Living modified organism' means any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology; h) 'Living organism' means any biological entity capable of transferring or replicating genetic material, including sterile organisms, viruses and viroids; i) 'Modern biotechnology' means the application of: a.* In vitro *nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles, or b. Fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection*".

GMO could mean any Genetically Modified Organisms, alive or dead but CPB is applicable only for LMO. As technology progresses many new applications and products are introduced and adopted. The definition given in CPB is flexible enough to be applicable to relevant developments. For example, while GM mosquitoes were not in the pipeline when CPB was negotiated and ratified, it will be covered by the definition of LMO given in CPB. While the scope of Article 26.1 covers all LMOs, this volume deals only with LMOs used in agriculture and Socio-Economic (SE) considerations related to them, as that was the mandate of the project which resulted in this volume. In the last chapter we discuss the relevance of CPB and SE assessment for Gene Drives and GM mosquitoes.

On account of developments like gene editing technology and whole genome sequencing, the questioning of (re) defining LMO/GMO for regulatory purposes becomes all the important.[1] Hence in future the distinction between GMO/LMO and non-GMO/LMO may not be what it is today. Perhaps, new terminologies may be developed to classify products developed using gene editing technologies. Even as the controversy over treating Gene Edited Crops as GMOs or not, rages on, new terminologies alone may not be sufficient to deal with Gene Edited Crops, The regulatory regimes may need a revamp and perhaps new principles and approaches may be necessary.

The roots of CPB can be traced to CBD. Article 19.4 of the CBD provides for Parties to "*consider the need for and modalities of a protocol, including advance informed agreement (AIA) in particular, to ensure the safe transfer, handling and use of living modified organisms derived from modern biotechnology that may have an*

[1] See Greenpeace (2015).

adverse effect on biological diversity and its components". Thus CPB is concerned about LMO for a specific reason and that resonates with the core objective of CBD.

1.2 The Making of CPB: A Brief History

The Conference of Parties (COP) to CBD held during November 28 to December 9, 1994 established a Open-ended Ad Hoc Group of Experts on Biosafety. This Group met in July 1995 and deliberated and was in favor of establishing an international framework on biosafety under CBD. This idea was taken up in the Second COP held in Jakarta in July 1995, resulting in formation of an Open-ended Ad Hoc Working Group on Biosafety (BSWG) to "elaborate, as a priority, the modalities and elements of a protocol". It took five years for negotiations and agreeing on a text that was to become CPB and in finally the COP held at Montreal in January 2000, CPB was accepted.[2]

While CPB is the first international Protocol that deals with biosafety aspects of Living Modified Organisms that are traded and could impact biodiversity, it is comprehensive enough to cover many aspects related to risk assessment, handling of LMOs, advanced information and prior informed consent, and liability and redress. In fact with hindsight we could say that as it is comprehensive it is well suited for applications like Gene Drives and GM mosquitoes. As CPB is not an instrument frozen in time, Parties by amendments and additions enhance its relevance and applicability. Hence in our view SE a consideration under CPB is also a topic that is relevant for such applications also.

In the negotiations, developing countries were concerned about the potential adverse impacts of LMOs and wanted to ensure that they did not become dumping grounds for LMOs that are unwanted and/or harmful. Those were the early years for GM crops and North–South divide was evident in negotiations. The South while willing to accept LMOs from North was also cautious enough to negotiate for provisions that would constrain attempts to dump or to mislead countries that are getting LMOs from other countries. For reasons of space and relevance we will not revisit the history of CPB and the negotiations that led to it and the positions took by different groups and countries and civil society groups. There is sufficient literature on this, for example *see* Bail et al. (2002).

1.3 Article 26.1: Scope and Objectives

Article 26.1 was accepted after many debates over the inclusion of an article on socio-economic considerations in the Protocol. While, the developing nations wanted to ensure that socio-economic considerations was incorporated as a basis for decision-making, developed nations opposed it by arguing that such considerations could not

[2] See http://www.biosafetyprotocol.be/history.html for an overview.

be quantified easily and so they should be left out of the Protocol. Another contention was that they should not be used as measures to avoid commitments and obligations under other conventions and treaties.

This divergence in views is discernible today on discussions on implementing Article 26.1 After protected negotiations it was agreed that socio-economic considerations could be incorporated in the text only if they were added with a rider that their application was consistent with existing international obligations, specifically the obligations under trade agreements. This compromise is reflected in the text of Article 26.1. This is not an unusual one as such a provision only ensures that the CPB is not perceived as a Protocol that is inconsistent with other Protocols/treaties and provides a way out to fulfil obligations under other Treaties,

Article 26.1 of the Protocol states

> The Parties, in reaching a decision on import under this Protocol or under its domestic measures implementing the Protocol, may take into account, consistent with their international obligations, socio-economic considerations arising from the impact of living modified organisms on the conservation and sustainable use of biological diversity, especially with regard to the value of biological diversity to indigenous and local communities.

Article 26.2 of the Protocol states

> The Parties are encouraged to cooperate on research and information exchange on any socio-economic impacts of living modified organisms, especially on indigenous and local communities.

According the Mackenzie et al. (2003) "*there must, first, be an "impact … on the conservation and sustainable use of biological diversity*" as a result of or "arising from" the trans-boundary movement, handling, and use of the LMO concerned. The "impact" referred to may include the potential effects of the LMO on biological diversity. Hence, where the introduction of LMOs under the Protocol affects biological diversity in such a way that social or economic conditions are or may be affected, a Party can use Article 26 to justify taking such impacts on its social or economic conditions into account for purposes of making decisions on imports of LMOs or in implementing domestic measures under the Protocol. Such social or economic impacts are generally referred to as secondary or higher order effects in technology assessment literature." (p. 164).

The CPB did not include socio-economic considerations for their own sake and they were included as they help in achieving the broad objectives of CPB and CBD. Thus socio-economic considerations should not be turned into a catch-all phrase or as an instrument to over ride objectives of other provisions of CPB/CBD. In this regard the IUCN Guide states

> Possible ways of taking socio-economic considerations "into account", especially with respect to indigenous and local communities, may include, for example
>
> - procedures for assessing and addressing socio-economic impacts in risk assessment and management; and/or

- subjecting decisions on import of LMOs to prior public consultation processes, especially with respect to communities that will be directly affected by the import decision – for example the local community in which the LMO is destined for field trial or use, or which may be affected by any potential adverse impacts of the LMO on biodiversity" (Mackenzie et al. 2003, p. 165).

Given the broad nature of socio-economic impacts, integrating them as part of approval/regulatory mechanism than as part of risk assessment/management, is preferable. Since impacts can persist over a long period, including, during the lifecycle of LMO, post-approval and post-marketing studies on socio-economic impacts are desirable. To include them in post-approval and post-marketing assessment processes for LMOs makes sense and this calls for specific plans on data collection (Chaturvedi et al. 2011).

The prior public consultations on import of LMOs can be part of approval/regulatory regime. In such a case which can call for response/input from public, prior to decision-making, but after, completing the field trials. The risk here that is that the public consultation process may be manoeuvred by some stakeholders and they may overwhelmingly influence the decision-making process in the name of public interest. Stakeholders who support/oppose import of LMOs may do so in different pretexts. Hence it is important that the public consultation process does not become yet another forum for endless debates. The process can be structured in such a way that no stakeholder is able to influence the process or the outcome.

Article 23 of CPB requires Parties to promote and facilitate public awareness, education and participation. Hence as public participation is integral to CPB, making that as part of SEA is essential to ensure that SEA provides enough opportunities to stakeholders to engage with the relevant parts of the SEA and express their views. In this volume, the views of different stakeholders have been studied and taken into account in the field work and data collection done by the six partner institutions. The chapters in Part II on Case Studies provide insights into the views of stakeholders. But as public participation is not limited to eliciting views or doing just surveys, it is suggested that the SEA process should have adequate scope for fuller and meaningful public participation. On the other hand, public participation should be understood and facilitated, as public perception and trust are playing a key role in accepting and adopting GMOs, or for that matter biotechnology, its applications and products.[3]

Interpreting Article 26.1 and giving effect to it has been challenging as there has been no consensus on what are the elements in SEC that have to be taken into account. As discussed elsewhere in this volume, the divergence in interpretation and putting Article 26.1 to practice is wide.

Ludlow, Smyth, and Falck-Zepeda take a position that Article 26.1 has a focus and can be read as an impact indicator, i.e. impact of LMOs on conservation and sustainable use of biological diversity and value of biological diversity to indigenous and local communities. (Ludlow et al. 2015). This narrow interpretation of the scope of Article 26.1 implies that only these matters under the Article and its implementation

[3]For an overview of public participation and CPB see Skarlatakis and Kinderlerer (2013), see also Quinlan et al. (2016).

should be done accordingly. But many Parties to CBD, particularly developing countries who were keen to include socio-economic considerations, envisaged a broader interpretation of the Article that facilitated such a consideration. Broadly speaking, there are two major approaches in taking into account socio-economic considerations. The first one is a narrow approach that often complements or linked to the risk analysis and under this socio- economic considerations are narrowly defined or only few issues are considered as relevant for socio- economic impact assessment. The approach in Argentina is an example for this and in some cases as in USA such an impact assessment is either not mandated or is undertaken in a limited way just to meet regulatory norms. The second approach takes into account the broader perspective and in this, implementing Article 26 is associated more with environmental impacts and sustainable development than with mere economic gains. This approach is exemplified in the Norwegian Gene Act and in rules and regulations of many European countries. Commentators have stressed the sustainable development dimension in CPB, particularly Article 26.1.[4]

1.4 Article 26.1, Article 26.2, CPB and Compatibility with Other Treaties/Agreements

The caveat in the Article on meeting obligations under other international agreements and treaties makes it clear that socio-economic considerations is not a ground for not meeting such obligations and measures taken when such considerations are taken into decision-making cannot override such obligations. About 170 Countries are Parties to CPB as they have ratified it (https://www.cbd.int/doc/lists/cpb-ratifications.pdf). But USA and Canada have not ratified CPB. Canada is a Party to CBD while USA is not a party to CBD and CPB. During the negotiations, the relationship between the proposed CPB and other agreements was a contentious issue. Given the predominance of WTO Agreements as global trade agreements, and, particularly the SPS Agreement for trade in LMO/GMO, should CPB be subordinated to WTO Agreements became a very contentious issue (Stabinsky 2000).

According to Gupta

> Given the multiple potential interpretations of the Protocol's decision criteria (including vis-à-vis the WTO), the Protocol's relationship to other international agreements such as the trade regime was explicitly on the agenda during its negotiation. To ensure that WTO obligations would not be superseded by the Protocol, the Miami Group of countries argued that the Protocol should contain a "savings clause" or a provision stating that nothing in the Protocol affects a country's obligations under other international agreements. Other groups, and especially the European Union, opposed inclusion of such a clause. These groups argued that a savings clause would negate the purpose of negotiating a biosafety protocol and would subordinate it to the WTO. This was one of the last issues to be resolved prior to finalization of the Protocol. The compromise reached does not include a savings clause in the operative articles of the Protocol, as desired by the Miami Group. However, it does include explicit

[4] Segger et al. (2013).

> language in the preamble about the relationship between the Protocol and other international agreements" (Gupta 2008, p. 32).

After analysing various provisions of CPB and WTO Agreements and the literature on trade and environmental laws, Sebastian Oberthur and Thomas Gehring state

> Overall, the provisions of the Cartagena Protocol relating to risk assessment, precaution and socio-economic considerations significantly limit the potential for conflict between the Cartagena Protocol and the SPS Agreement. In particular, no obvious incompatibilities exist, so that countries do not face the choice between the Scylla of not complying with the SPS Agreement and the Charybdis of not fulfilling their obligations under the Cartagena Protocol. Both instruments can be interpreted in mutually supportive ways. At the same time, there is no certainty that the two agreements will be interpreted in compatible ways. Since the area of compatible interpretations has loose boundaries, different actors may arrive at different interpretations and may wish to exploit the room for manoeuvre that exists in this respect.6 Therefore, a limited potential remains for interpreting in varying ways what may be considered "compatible" or "mutually supportive (see e.g. Eggers and Mackenzie 2000; Stoll 2000; Gupta 2001; Cottier 2002; Howse and Meltzer 2002; Safrin 2002; Rivera-Torres 2003) Oberthür and Gehring 2008, pp. 109–110.

After ratification of CPB, there were concerns about compatibility between WTO Agreements and CPB but today they seem to be exaggerated, partially because there has been no dispute before WTO on this issue. Another factor is that perhaps no country has invoked CPB to curtail or renege its obligations under WTO Agreements or any other international treaty. With moratorium in place, cultivation of GM crops in Europe is almost nil and trade in GM products for use as feedstuff was least controversial, As a result, adoption of SE concerns did not result in any conflict or contravention. But it cannot be said that in future no such conflict would arise.

While in the earlier years concerns were more on compatibility between CPB *per se* and international agreements, the discussion on Article 26.1 in this was limited since it was not implemented. Biosafety regimes and regulations on biotechnology expanded considerably in the first decade of the millennium as many countries approved cultivation and/or, trade in GM products and also started giving effect to Article 26.1. But so far there has been no issue of implementing Article 26.1 being considered as contravening provisions of WTO Agreements. A major reason is that countries have ensured that Article 26.1 is implemented in such a way that it is compatible with biotechnology regulations and risk assessment regimes. Another factor is that countries have chosen to interpret Article 26.1 in many ways as CPB does not define SEC nor explicitly indicates what are the core elements for doing SE assessment or considering SEC in decision-making.

Socio-economic considerations can at the best contribute to decision-making and as such they themselves have nothing to do with obligations under other treaties. So, whether the decisions taken or the resulting action would be in violation of other obligations is an issue that has to be understood in a specific context. One approach to understand the compatibility issue has been discussed by Ludlow, Smyth and Falck-Zepeda in their presentation made in 2015 (Ludlow et al. 2015). Taking into account the five dimensions of socio-economic considerations, i.e. economic, human health-related, social, ecological, and cultural/traditional/ethical/religious, they have developed a matrix to map both the obligations under the relevant agreements and socio-economic considerations. They have considered food security as a component of social dimension. They identified the issues in defining the relevant SECs such as whether LMOs improve food security versus LMOs undermine food security. On the basis of their analysis they have concluded that each nation should determine its international obligations landscape in giving effect to SECs.

According to Ludlow, Smyth and Falck-Zepeda "*Looking across all five dimensions, common problems arise for nations seeking consistency between SEC assessments and obligations under other international agreements. These problems occur at both the international (i.e., between nations) and national (i.e., within a nation) levels. They must be addressed if the CPB regime is to successfully progress. The most important problem at the international level is the urgent need for clear definitions of SECs. The "food security" SEC discussed in the social dimension above illustrates definitional difficulties. Identification of conflicting obligations under other international agreements cannot occur without settled definitions. A second problem at this level is inconsistency in the focus/context of CPB obligations with that of other international agreements. This can make compliance with obligations under other agreements difficult*" (Ludlow et al. 2016, pp. 162–163).

Table 1.1 sums up the five dimensions across the different agreements and conventions vis a vis CPB.

With respect to indigenous communities, ILO Convention 169 is the most relevant convention and hence in terms of socio-economic considerations it is important that the processes for conducting SEA do not go against that Convention. So taking into account the relevant provisions of ILO Convention 169 and relevant articles in CBD, Nagoya Protocol on Access and Benefit Sharing, the rules and processes relating to SEA or giving effect to Article 26.1 can be formulated.

1.5 Developments in the CPB Process

What are the elements relevant for SECs and in interpreting and implementing Article 26.1 is obviously important. Over the years the COP-MOPs were often used as fora to debate the relevant SECs and on implementing Article 26.1. NGOs like Third World Network, organizations representing many European Governments have been promoting a broad approach to SECs stressing the risks to environment and biodiversity, the potential adverse impacts on food security and small and medium farmers and insisting for a comprehensive framework in SEC and SE assessment.. For example the Netherland's Commission on Genetic Modification (COGEM) in the report published in 2014 identified benefit to society, economics, and prosperity and cultural heritage as three major criteria for identification of SECs.[5] Given the issues of co-existence between GMO plants and non-GMO plants and consumer choice and labeling being hotly debated in Europe, they also found a place in reports on

[5] COGEM (2014).

Table 1.1 Key attributes of international agreements and organizations relevant to SEC assessment in agri-bio regulation

Agreement	Objective	Parties	Express reference to Biotech/GMOs	Legally binding	Enforcement mechanism
Cartagena Protocol on Biosafety (CPB)	Regulates international transboundary movements of GMOs	168 members	Yes	Yes	No
Economic dimension					
WTO Agreements • SPS Agreement • TBT Agreement • GATT	Creation of non-discriminatory free trade	160 members	No (although is specific reference in standards of Codex, OIE and IPPC)	Yes	Yes, including trade sanctions
Codex Alimentarius Commission (Codex)	International food standards, guidelines and codes of practice	186 members	Yes	No (although often adopted by national legislation/ through WTO agreements)	No (although may be relevant through national legislation/ WTO agreements)
ILO Conventions, including ILO Convention 169	Social justice, particularly labor standards	185 members but not of all conventions	No	Yes	Yes

Source Ludlow et al. (2016, pp. 165–166). See source cited for other dimensions

SEC from European agencies. This is not surprising but it represents one perspective. Industry groups on the other hand argued for an interpretation that limited the scope of SEC and its application in decision-making.[6]

They contend that SECs should not be interpreted broadly in the name of comprehensive framework. According to them, text of Article 26.1 has limited SECs to few specific issues and hence only those issues should form the basis for SEC in decision-making. As discussed in the Chapter on International Experience in implementing Article 26.1, countries have avoided both the extreme views and have given effect to Article 26.1 in many ways, while trying to balance interests of stakeholders. Another interesting aspect is that while in the negotiations there was a clear North

[6]E.g. https://croplife.org/wp-content/uploads/pdf_files/Socio-economic-Considerations-in-Decision-making-on-LMOs-MOP-6.pdf.

South divide; in implementing Article 26 the picture is not as simple as that, given the diversity in implementation in terms of principles and objectives. In the COP held in 2008 it was decide that technical guidance was necessary and information on national experience should be collected. On this basis, a survey was organized and the results were published as a document.[7]

In 2012, in the COP-MOP held at Hyderabad, the results were discussed. The survey showed that the five most important SECs are food security, health-related impacts, co-existence of GMOs (and non-GMOs), impacts on market access and compliance with biosafety measures. The following were also identified as important SECs:

- Impacts on conservation and sustainable use of biodiversity
- Economic impacts of changes in pest prevalence
- Macroeconomic impacts
- Farmers' rights
- Intellectual Property
- Consumer choice, and,
- (impact on) Indigenous and local communities

The Parties decided to establish an Ad hoc Technical Experts Group (AHTEG)[8]. In 2014 the AHTEG presented a report to COP-MOP on SE Considerations.[9] The Group suggested ten general principles, examined the methodological considerations and made suggestions. The ten identified dimensions are: (a) Economic: e.g., impact on income; (b) Social: e.g., impact on food security; (c) Ecological: e.g., impact on ecosystem functions; (d) Cultural/traditional/religious/ethical: e.g., impact on seed saving and exchange practices; (e) Human health-related: e.g., impact on nutritional status. It also made the following points:

1. Only indicative list is feasible and that would be non-exhaustive. 2. Listing and identifying relevant elements of socio-economic considerations based on existing experiences is essential to move forward. 3. Elements of socio-economic considerations may be classified by adopting the ten dimensions. 4. Human health-related and ecological dimensions that are not addressed in risk assessment may be addressed when taking socio-economic considerations into account.

This approach by the group is a pragmatic approach as it favors neither a too broad perspective, nor suggests a too narrow perspective. Further, it has listed the key dimensions in SECs while conceding that any list of such elements would be indicative only.

The final report was an important step in bringing conceptual clarity in SECs. Although there was no consensus on the AHTEG Report that was not surprising. By decision BS-VII/13, in COP-MOP held in 2014, the Parties extended the AHTEG and suggested that it should continue its future work in a step wise approach: "*At its seventh meeting, the COP-MOP took note of the report of the* Ad Hoc *Technical Expert Group on Socio-economic Considerations (AHTEG). In decision BS-VII/13, Parties*

[7] See p. 125 of Ludlow (2015) for details.

[8] http://bch.cbd.int/onlineconferences/portal_art26/se_main.shtml.

[9] https://www.cbd.int/doc/meetings/bs/bs-ahteg-sec-01/official/bs-ahteg-sec-01-03-en.pdf.

extended the AHTEG and determined that it should work, in a stepwise approach, on: (i) the further development of conceptual clarity on socio-economic considerations arising from the impact of living modified organisms *on the conservation and sustainable use of biological diversity, and (ii) developing an outline for guidance with a view to making progress towards achieving operational objective 1.7 of the Strategic Plan and its outcomes*."

1.6 Developments Related to AHTEG

Although it was termed as an Ad hoc Technical Experts Group, over the years AHTEG has been active and continuously produced documents for consideration of the Parties to CPB. The CPB website provides details of the activities and outputs from AHTEG.[10]

In the 9th COP-MOP held at Sharm El-Sheikh, Egypt, November 17–29, 2018, the document CBD/CP/MOP/9/10 containing "Guidance on the assessment of socioeconomic considerations in the context of Article 26 of the Cartagena Protocol on Biosafety", was presented. According to CBD website "*The COP-MOP extended the* Ad Hoc *Technical Expert Group on Socio-economic Considerations to review the outcomes of the online forum and requested the Executive Secretary to convene a face-to-face meeting of the Group. The COP-MOP decided to consider the outcomes of the process at its tenth meeting*".[11]

The document from AHTEG is a welcome step forward as it outlines specific steps and provides clarity on doing SEA and also outlines a process to do a SEA. It provides an operational definition and principles for assessment of socio-economic considerations. The operational definition is "*Socio-economic considerations in the context of Article 26 of the Cartagena Protocol may, depending on national or regional circumstances and on national measures to implement the Protocol, cover economic, social, cultural/traditional/religious/ethical aspects, as well as ecological and health-related aspects, if they are not already covered by risk assessment procedures under Article 15 of the Protocol*".

This definition indicates that the key elements to be considered include economic and non-economic aspects and states that they should be covered if they are not already covered by risk assessment procedures under Article 15 of CPB. In terms of practice this means that if risk assessment does not cover them, then the recommendation would be to go beyond risk assessment and do additional assessment to cover them. As it does not differentiate among economic and non-economic aspects, it is obvious that AHTEG takes a wholistic perspective on SEC. Moreover it also states

> The assessment of socio-economic effects may cover the following aspects: • Relation between the impact of the living modified organism and the socio-economic effects; • Beneficial or adverse nature of the effects; • Likelihood of effects to occur; • Intensity or magnitude

[10] https://bch.cbd.int/protocol/cpb_art26_info.shtml1/2.

[11] https://bch.cbd.int/protocol/cpb_art26_info.shtml1/2.

of the effects; • Possible downstream and cumulative effects; • Reversibility of the effects; • Mitigation of the effects; • Effects on different communities and groups, in particular vulnerable or marginalized groups and indigenous peoples and local communities; • Anticipated onset and duration of the effects (e.g. sustainability and persistence) (P8 CBD/CP/MOP/9/10)

Although the term used here is "may" it can be interpreted that AHTEG suggests that these should be covered, and when read with what the document says on methodology of data and aspects of assessment, it becomes clear that AHTEG has taken a pragmatic perspective on this, as the objective of the exercise is not to collect data and do assessment for their own sake.

We think that this is an important step forward and can be used to refine current guidelines on doing SEA and to establish new guidelines where none is available. Having said that we think that the suggestions in this document should also be tested against the current practices to get an idea as to what aspects are covered and how the SEA process is structured and operationalized. Such an exercise will enable countries to evaluate their practices and guidelines and also assess how relevant and practicable the guidelines and processes suggested are.

As the next COP-MOP will review this and outcomes of this process, the interregnum period can be productively used to take the process forward and to revisit the current practices. We hope that this will enable in moving forward in SEC and will also answer some of the questions raised by critics on lack of definition and lack of clarity on SEA. The next COP-MOP can consider converting AHTEG into a permanent working group and extend it's mandate to cover new technologies and SECs.

1.7 Literature Review of Socio-Economic Studies on GM Crops in India

Ever since the commercialization of *Bt* Cotton began in 2002 in India, there have been many studies conducted to assess its socio-economic implications. Most of these studies have been of *ex-post* type (Appendix Table 1.2). These studies have been carried out both by Indian researchers as well as foreign researchers across many states and regions in India. There have been a very limited *ex-ante* socio-economic assessment studies on the crops that are yet to be approved (Appendix Table 1.3).

The various parameters and variables that were selected for carrying-out these studies included yield gain, productivity increase, net profit gain, reduction in insecticide use, labor use, etc. There have been only a few studies that were undertaken to study the perception and diffusion parameters.

In a way, the meta-analysis of these studies clearly indicates that the majority of these studies have been undertaken to assess the economic impact of GM crops both at the farm level and at the level of individual farmers.

Majority of the studies on *Bt* Cotton found positive results of using *Bt* Cotton over non-Bt varieties. They found higher gross margins per hectare on Bt cultivated lands. The various reasons for this could be increase in yield, decrease in input costs or savings in terms of labor and insecticides usage, etc.

Few studies also found no benefits for farmers from the introduction of *Bt* seed varieties. Couple of studies even criticized the results of pro-*Bt* studies by claiming that more reliable data from the public state university-led trials had shown higher yields for non-Bt varieties than for the *Bt* hybrids.

1.7.1 Meta-Analysis of the Studies

There have been many meta-analyses done on the performance of GM crops worldwide (including India). These meta-analysis studies conducted by Klumper and Qaim (2014), Racovita et al. (2014), Raney (2006), Qaim (2009), Tripp (2009), Smale et al. (2009), Finger et al. (2011), Areal et al. (2013), and Fisher et al. (2015) have shown that there were reductions in yield damage by insects, reductions in insecticide applications for target insect pests, decreases in management time and increases in gross margins, due to adoption of GM crops.

A meta-analysis of the findings of 147 studies of HR soybean, maize, and cotton and Bt maize and cotton in 19 countries (including India), conducted by Klumper and Qaim (2014) found that because of the increased yields (21.5%) and decreased insecticide costs (39%), profit increased by an average of 69% for adopters of those crops.

A meta-analysis of studies conducted in 16 countries (including India) reported that gross margins were higher on the average for the GM varieties, in large part because of their greater yields, even though the production costs were greater for GM varieties than for non-GM varieties (Areal et al. 2013).

Raney (2006), in another such study, conducted in Argentina, China, India, Mexico, and South Africa; found that GM cotton, maize, and soybean provided economic gains to the farmers who adopted them; however, the impact was varied according to the domestic institutional capacity to enable poor farmers gain access to suitable innovations.

Choudhary and Gaur (2010) in their analysis of thirteen studies done in the period 1998–2010, covering both pre and post-commercialization of Bt cotton in India, found that all these studies consistently confirmed 50–110% increase in profits from Bt cotton (in comparison to conventional), equivalent to range of USD 76 to USD 250 per hectare. They also argued that these profits mostly accrued to small and resource-poor cotton farmers in various cotton growing states of India. They also argued based on a study that use of Bt cotton in India had led to massive gains in women's employment in India during that period.

Choudhary and Gaur (2015) in their later assessment, based on various studies, found that 7.7 million small holder cotton farmers having an average land holding of less than 1.5 hectares benefited from planting Bt cotton in 95% of 12.25 million cotton area in India. Moreover, they argued that India enhanced farm income from Bt cotton by USD 16.7 billion in the twelve year period 2002–2013, which is quite remarkable.

Saravanan and Mohanasundaram (2016) in their analysis of the studies done on development and adoption of Bt cotton in India found that Bt cotton had helped to reduce chemical sprays, thereby contributing to cleaner environment. They also found that Bt-cotton offered protection from bollworms, leading to a healthy crop, better boll retention, greater harvest and more profit.

Gandhi and Jain (2016) in their analysis, based on four studies done by various researchers, in four states viz. Andhra Pradesh (Ramgopal 2006), Gujarat (Shah 2007), Tamil Nadu (Pushpavalli 2004) and Maharashtra (Gandhi and Namboodiri 2009) found that the average number of pesticides as well its cost per hectare was lower for the BT-cotton in all the four states. Similarly, the yield of Bt-cotton was found to be higher over the non-Bt cotton. They also observed that the cost of cultivation per hectare of Bt-cotton was higher than of non-Bt cotton in all the states studied, however, the value of output and profit was found to be higher in the case of Bt-cotton in all these states. This implied that the benefit–cost ratio of Bt cotton has been found to be higher than that of non-Bt cotton in these four states. Gandhi and Jain (2016), after conducting their econometric analysis of the whole sample, indicated that the positive impact of Bt cotton on the yields had strong statistical significance.

Few *ex-ante* Indian studies done on yet-to-be-approved GM crops have estimated that there will be net profits to the farmers at all levels. This will be due to enhanced yield, decrease in input cost or due to savings on insecticides and labor, etc.

1.7.2 Socio-Economic Assessment Studies of Bt Cotton in India

In this section we provide a summary of major studies on SE Assessment of Bt Cotton in India. Most of the studies paid attention to economic gains/benefits and not all studies indicated that all farmers benefitted. Instead of generalizing we are providing the findings from the studies with details so that nuances in the findings can be understood.

The study done on the Bt Cotton prior to its approval for cultivation by Naik (2001) indicated that there will be an economic advantage in the range of USD 76 to USD 236 per hectare for the Bt Cotton farmers, which did came out to be the case later, as documented by many ex-post studies.

On their study, based on data collected from 150 farmers in 2003 from two districts in the Vidarbha region of Maharashtra, Narayanamoorthy and Kalamkar (2006) found relative advantages of Bt over non-Bt hybrids.

Based on their analysis of over 9000 cotton plots, Bennett et al. (2006) and Morse et al. (2005) found that the gross margins per hectare were higher on Bt plots than on non-Bt ones. Further, employing a large sample of pooled cross sectional and time-series data recorded at the plot level, Bennett et al. (2006) concluded that there were temporal and spatial variations in the productivity of Bt cotton. They found that farmers did not benefit at all in some areas of Maharashtra.

On their survey of 341 cotton farmers in 2002 across Andhra Pradesh, Karnataka, Maharashtra, and Tamil Nadu, Naik et al. (2005) and Qaim et al. (2006) observed the heterogeneity among farmers in terms of agro-ecological, social, and economic conditions.

On the basis of data from on-farm trials of approved cotton hybrids in Madhya Pradesh, Maharashtra, and Tamil Nadu, Qaim and Zilberman concluded higher estimate of the yield advantages of Bt cotton hybrids (80–87%) (Qaim 2003; Qaim and Zilberman 2003).

Barwale et al. (2004), found higher yield advantage (by 30%) for Bt hybrids over non-Bt hybrids, as well as higher net profits, lower usage of pesticides, and better quality of cotton. Subramanian and Qaim (2010) found that there was a higher generation of income and employment of rural labors, especially female labor, through the plantation of insect-resistant Bt cotton. The study also indicated a rise of total wage income by USD 40 per hectare as compared to the conventional cotton.

Various other studies such as Qaim et al. (2006), Bennett et al. (2006), Gandhi and Namboodiri (2006), Subramanian and Qaim (2010), Sadashivappa and Qaim (2009), Subramanian and Qaim (2010), have confirmed 50–110% increase in profits from Bt Cotton as compared to the conventional cotton. The rise of the productivity was found to be in the range of 30–60%, whereas the reduction of the number of sprays of insecticides averaged at around 50%.

Qaim (2006) found that there were 50% reductions in the number of sprays, 34% increase in yield, and net profit increase by USD 118 per hectare for the Bt Cotton cultivating farmers. Bennett et al (2006) found that significant yield gains of Bt Cotton. Gandhi and Namboodiri (2006) found 31% yield gains, 39% reduction in number of pesticide and an increase of USD 250 in profit per hectare. Subramanian and Qaim (2010) observed 30–40% increase in productivity and 50% reduction in the insecticide quantities, resulting in net increase in the profit per hectare by USD 156. Sadashivappa and Qaim (2009) found that the adoption of Bt Cotton has resulted in 43% rise in yield, 21% decline in the number of insecticide sprays and 70% increase in net profit margins as compared to the conventional cotton cultivation.

Ashok et al. (2012) in their study involving survey of 480 farmers from four states (Maharashtra, Gujarat, Andhra Pradesh and Tamil Nadu) found that the farmers in these major cotton growing states in India benefitted significantly from adopting Bt technology through higher profitability, which was mainly due to reduced pest control costs and higher yields, though there was considerable variation in key variables like yield, cost, pesticide use, etc.

In a study based on a panel data collected between 2002 and 2008, Kathage and Qaim (2012) showed that Bt caused a 24% increase in cotton yield per acre through reduced pest damage and a 50% gain in cotton profit among smallholders. They further argued that Bt cotton adoption raised consumption expenditures, a common measure of household living standard, by 18% during the 2006–2008 period. It was concluded that Bt cotton created sustainable benefits for the farmers during the period of study.

Sadashivappa (2015), based on biennial panel data over a period of five years, found that number of insecticide sprays and insecticide amounts used were significantly lower on Bt than on non-Bt plots. He also found that there has been a significant yield advantage due to lower crop losses, owing to adoption of Bt cotton. In the period of study, it was found that agronomic and economic advantages had been sustainable.

All these studies have adopted different methodologies such as Cob-Douglas method, partial equilibrium, economic surplus method, cost–benefit analysis, probit model etc. to estimate the economic impact of the Bt Cotton. These studies have used primary data (collected from the farmers) using multi-stage stratified random sampling across many states and regions. The increase in the benefits from the farm level has been attributed to the savings in the insecticide use and higher yields, despite higher seed prices.

However, some studies are critical about the impact of Bt technology in India. Among the critics, Sahai and Rahman (2003), based on their random survey of 100 farmers in Maharashtra and Andhra Pradesh during the first season after the approval of Bt cotton hybrids, found that the net profit from Bt cotton was lower in all types of plots. They also observed that the cost of seed of Bt hybrids was four times more than that of non-Bt hybrids. In 2004, the same authors implemented another survey in four districts of Andhra Pradesh and reported economic losses for 60% of farmers growing Bt cotton hybrids.

Kuruganti (2009) concluded that in Gujarat, the high yield in cotton was due to the low incidence of the target pest, good monsoon, increased irrigated area and high application of fertilizers.

There are not many studies done to gauge perception of the consumer on the issue in India. Deodhar et al. (2007), in their perception survey of 602 respondents in Ahmedabad and 110 respondents online, tried to analyze the issues of consumer awareness, opinion, acceptance and willingness to pay for GM foods in the Indian market. They found that more than 90% of the respondents did not have any knowledge about GM foods. However, once they had been informed about the benefits and consequences of GM foods, more than 70% were willing to consume GM foods, even if GM and non-GM foods were available for the same price. On an average, the authors found that consumers were willing to pay higher premiums for golden rice and GM edible oil.

Arora and Bansal (2011) in their study analyzed impact of seed price interventions and technological development on diffusion of Bt cotton in India, using state level data for the period 2002–2008. They found that a decline in seed prices will lead to an increase in the diffusion rates.

Lalitha and Viswanathan (2015), based on their study on technology diffusion and adoption in cotton cultivation in Gujarat found that the information about refuge and other safety measures were limited to small percentage of farmers. Given the scenario, they argued that the lack of extension service results in inappropriate and misuse of technology and there is a need to reform entire extension system so that bio-safety measures are effectively followed.

1.7.3 Ex-Ante Studies on Yet to Be Approved GM Crops in India

Based on the secondary data from South Zone (TN, AP, Karnataka), North Zone (Punjab, Haryana, UP), East Zone (WB), West Zone (MP, Maharashtra) and farm level data from 150 rice farmers from TN and Chhattisgarh, Ramasamy et al. (2007) in their study, on drought and salinity tolerant rice, found that there was a yield gap w.r.t. experimental yield, adoption of drought and salinity resistant transgenic was projected to bring additional income to farmers, despite an increase in seed cost and the cost of rice seed was projected to be about 15.5% higher than for the existing high yielding varieties and the level of use of other inputs should remain about the same (i.e., labor, fertiliser, pesticide). It was also concluded that the yield of rice would be 25% higher as compared to existing varieties under stress conditions.

Based on survey interview of 80 groundnut and 30 sunflower growers and 16 scientists from AP, Karnataka and Gujarat, Selvaraj, Ramasamy and Norton (2007) in their study, on tobacco streak virus resistant in groundnut and sunflower, found that adoption of transgenic TSR-resistant groundnut would bring 90% higher profits to the farmers despite an increase in the cost of seeds of 20% compared to existing varieties. They also estimated 8% reduction in labor use due to reduction in application of fungicides. The total returns would be Rs. 38556 per hectare in case of TSVR groundnut, compared to Rs. 26792 for existing varieties. Thus, they argued that adoption of transgenic TSVR sunflower would bring 150% higher profits per hectare despite increase in seed cost of 20%. They also observed that yield of TSVR sunflower would be 20% higher than existing varieties such as Ganga Cauvery, Kargil and Suntech 120 and cultivation of TSVR groundnut and sunflower would bring benefits in terms of high yield, low production cost and high income.

Based on the farm survey of 30 potato growers and 4 scientists in CPRI (Shimla), Selvaraj et al. (2007) in their study on late blight-resistant (LBR) potato, concluded that there will be 25% higher yield of LBR potato, reduced pesticide application costs by INR 1100; reduction in labor use by 11% due to reduced application of fungicides. The study also observed that farmers would incur Rs. 73246 per hectare in cost of cultivation of LBR potato, as compared to Rs. 68893 for existing varieties due to higher seed costs (20% more) for the GM potato, but total returns would be Rs. 190000 per hectare in case of LBR potato as compared to Rs. 127000 for existing varieties.

Based on field trial data carried out by Mahyco in several locations in several states, interviews of 360 Brinjal farmers in three leading Brinjal-producing states (AP, WB, and Karnataka) and consumer surveys (645 households from five locations), Krishna and Qaim (2007), in their study, found that yields of Bt hybrids were double than those of non-Bt hybrids.

Based on the data on production and prices of Brinjal at all-India level and for selected regions covering farmers growing Brinjal in the major states such as West Bengal, Gujarat, Eastern UP and Bihar and Karnataka, Kumar et al. (2011) in their study, found that there would be higher yield due to reduction in crop damage from SFB infestation (yield gain of Bt hybrids was 37.3% over non-Bt hybrids and 54.9% over popular hybrids); reduction in cost due to savings in insecticide use to control SFB (reduction by 41.8%). They also concluded that the quality would be better which will lead to enhanced market acceptability and will provide a premium price. Consumers, on the other hand, will benefit from better quality produce which will be free from SFB infestation and residues of chemicals; lower price (3–15% less); and higher accessibility to brinjal due to increased production. In terms of regional distribution effects, the major share of welfare gains would happen in the eastern states (WB, Odisha, Bihar), where most of the brinjal is produced and insect or pest problem is severe. The researchers also concluded that the development of Bt OPV will improve access to resource-poor farmers to technology; who might not adopt more expensive Bt Hybrids due to income constraints.

1.7.4 Comments on the Studies and Need for More Informed Studies

Some researchers have questioned the validity of many of the studies conducted on account of the possible effect of biases. Stone (2012) argued that estimates quoted by the studies are largely uncited and unverifiable claims. He also said that many of the studies showing favorable results for GM crops were authored by employees of biotech firms themselves.

Rao (2013) however, dismissed the argument that shortcomings in Bt cotton studies and divergence between yield gains and extent of adoption of Bt hybrids made it impossible to conclusively say anything about the impact of genetically modified seeds. He argued that there have been numerous studies that have controlled for selection and cultivation bias, and concluded that Bt cotton has had statistically significant positive yield effects. Catacora-Vargas et al. (2018) have pointed out the limitations of the studies on socio-economic impact assessment and argued "Adequate SEI scientific practice related to GM crops will require acknowledging the limitations of single-discipline economic, econometric and related methods, and—even when social dimensions are investigated—the shortterm quality of most current research. To advance on this, toward more realistic in-context trajectory evaluations (Ely et al. 2014; Herrero et al. 2015; Leach et al. 2010; Pavone et al. 2011) a key step would be to overcome the inconsistency of appraising long-term global development goals (e.g. hunger- and poverty-reduction) by using only short-term studies (Ervin et al. 2011). By doing this, SEI research, publication and debate will develop more legitimate authority for itself, contributing also to identifying and answering further biosafety policy-relevant research questions, such as "what are the real social and economic effects of GM crop-adoption?" "on which groups and in which ways?", "under which local conditions?", "for how long time?", "who gets excluded and why?", "what are the indirect social and environmental costs?", and perhaps most crucially, "could GM crops bring real, sustained social benefits if governed and developed under a different political economy?" Addressing these questions will also require public and open deliberations with a broader range of informed policy actors and stakeholders than has hitherto prevailed."

Given this scenario, it is evident that we need more studies that go beyond the shortcomings pointed out by Catacora-Vargas et al. (2018). The present book has attempted to fill that gap and intends to present a scenario based on extensive field surveys across six states in India.

1.8 Conclusion

In the past 15 years or so, much has happened in terms of implementing Article 26.1. While it cannot be said that it has been adopted by all the countries, significant progress has been made. As discussed elsewhere in this volume, the diversity in implementation shows that countries are interested in implementing it as it is very relevant for regulation and governance of LMO/GMO. Although there has been a view that the concept of SEC lacks clarity and there is no working definition that would reduce, if not eliminate the ambiguities in interpretation and implementation, this lack of clarity does not seem to have been a constraint. The Secretariat of CPB has also enabled implementing Article 26.1 through discussions, and by establishing AHTEG it has taken the debate on Article 26.1 forward. The AHTEG has contributed in identifying the key elements in SEC and has also brought to the fore the need to discuss and think further on Article 26.1. Thus to state that implementing Article 26.1 has been progressing well is not an exaggeration. In the initial years of CPB there were debates about its relationship with other treaties/agreements, particularly with WTO agreements and whether there would be incompatibilities or conflicts among trade and environment agreements. But over the years there has been no such conflict between CPB and other agreements and it also indicates that countries have tried to harmonize implementing CPB with their obligations under various agreements/treaties.

The literature survey indicates that most of the studies have been on economic gains/benefits and related themes. Other themes such as environmental impacts, health impacts, and impact on gender and employment have not received the same attention. While taking SEC in decision-making findings from studies that address different themes/issues are important so that the decision makers can get a wholistic understanding of the impacts and will not be misled by positive claims on economic gain. We hope that the guidelines and methodologies espoused in this volume would enable conducting a comprehensive SEA and thus will help in considering SEC in decision-making. The focus on economic gains is not limited to studies in India as most of the studies done in other countries are also on economic gains/benefits. Hence we suggest that more studies are needed and they have to be multi-dimensional. There is a need for long-term studies and studies at different phases in the life cycle of LMOs. We have made some suggestions on this elsewhere in this volume.

Finally there is a need to revisit both the theory and practice in doing SEA or considering SEC as new technologies are likely to pose new challenges in implementing Article 26.1.

Appendix

See Tables 1.2 and 1.3.

Table 1.2 Ex-post studies on Bt Cotton in India

Study by	Criteria/Focus	Methodology
Ashok et al. (2012)	Economic and environmental impact	Economic analysis and impact quotient
Haque et al. (2015)	Productivity	Cob-Douglas method
Ranganathan and Gaurav (2013)	Yield (kg/ha) Price (Rs./quintal) Revenue (Rs./ha)	Variance Decomposition Analysis
Kumar et al. (2011)	Yield gain (reduction in crop damage from FSB infestation) Reduction in application of insecticide use Benefits to Brinjal farmers (reduction in insecticide use, reduction in labor) Benefit to consumers (reduced price due to higher volume produced)	Multi-stage stratified random sampling
Mal Puran et al. (2011)	Environmental impact (insecticide use) Yield (kg) Fertilizer used (kg) Labor used (days)	Data envelopment approach (Cobb–Douglas production function)
Rao and Dev (2009)	% change in yields (pest infestation) Net income in Bt cotton versus non Bt (revenue- rental value of land, fertilizer, pesticide family labor etc.) (Rs./acre) Poverty Reduction ((Employment) (Days)	Multi-stage stratified random sampling
Sadashivappa and Qaim (2009)	Total cost (manure, fertilizer, labor, insecticide, irrigation) Revenue (yield (kg/acre), output price(Rs/kg)) Profit(revenue–cost)	Stratified random sampling procedure

(continued)

Table 1.2 (continued)

Study by	Criteria/Focus	Methodology
Krishna Vijesh et al. (2009)	Yield (quintal/acre) Cost (manure, fertilizer, Labor, Insecticide, Irrigation) (Rs./acre)	Tobit model and Cobb–Douglas production function
Kolady and William (2008)	Yield (quintals/acre) Factors influencing yield (fertilizer use, pesticides use, irrigation use, labor use)	Weibull production function
Peshin et al. (2007)	Input use(fertilizer use, seed, pesticide) {kg/ha} Productivity (insect pest losses caused by bollworm) {q/ha} Yield Pesticide cost (Rs./ha)	No methodology given
Krishna and Qaim (2007)	Cost (seed, insecticide, labor cost, harvesting cost) {Rs./acre} Yield (quintals/acre) Gross revenue (Rs./acre) Gross margin (Rs./acre)	Partial equilibrium
Morse et al. (2005)	Output (yield comparison (quintals/acre) Total cost (seed use, fertilizer use, insecticides for bollworm control, irrigation use, labor use) (Rs./acre) Gross margin (revenue–total cost)	One way ANOVA table
Narayanamoorthy and Kalamkar (2006)	Total cost (seed cost, insecticide, fertilizer, manure, labor, harvesting cost) {kg/acre} Revenue (yield (kg/acre), output price (Rs/kg)) Net revenue (revenue–total cost)	Linear regression

(continued)

Table 1.2 (continued)

Study by	Criteria/Focus	Methodology
Qaim et al. (2006)	Cost of production across social categories Impact on employment across social categories	Multi-stage random sampling procedure
Dev and Rao (2007)	Yield and pesticide use Cost and returns Cotton quality	Multi-stage stratified random sampling
Gandhi and Namboodari (2006)	Cost (seed, insecticide, fertilizers, manure, labor, harvesting) Revenue (yield, output price) Gross margin	Regression analysis
Naik et al. (2005)	Insecticide savings (insecticide use) Reduction in losses due to pests Output (production)	Multi-stage area random sampling
	Cost of cultivation (labor, seed cost, fertilizer, pesticide, irrigation cost) Cotton yield (kg/ha)	No methodology given
Orphal Jana (2005)	Expenditure (seed use, manure, inorganic fertilizer use, insecticide use, irrigation use, labor) (Rs./acre) Yield (kg/acre)	Descriptive statistics and statistical tests
Morse et al. (2005)	Total cost (seed use + insecticide use) [Rs./ha] Revenue (cotton yield + price of cotton) [tonnes/ha + Rs./tonne] Gross margin (revenue–total cost) [Rs./ha]	General linear model approach
Qayyum and Sakkhari (2005)	Yield	440 farms; no methodology given
Bennett et al. (2006)	Pesticide use Pesticide cost Yield	No methodology given

(continued)

Table 1.2 (continued)

Study by	Criteria/Focus	Methodology
Shiva and Jafri (2004)	Yield per acre Staple size Seed cost Income	Field study in Maharashtra, MP, AP and Karnataka
Qaim and Zilberman (2003)	Yield (quintal/acre) Pesticide use Investment in Bt and non Bt (Rs./acre)	157 farms; Cobb–Douglas production function
Sahai and Rahman (2003)	Yields	No methodology given

Source Compiled by authors

Table 1.3 Ex-ante studies on GM crops in India

Sl. no.	Study by	Crop	Sample and methodology	Findings
1	Ramasamy et al. (2007)	Drought and salinity tolerant Rice	– Secondary Data: South Zone (TN, AP, Karnataka), North Zone (Punjab, Haryana, UP), East Zone (WB), West Zone (MP, Maharashtra) – Farm level Data: 150 rice farmers from TN and Chhattisgarh – Economic surplus method	– Yield gap w.r.t. experimental yield (Max. yield gap was noticed in UP with 3728 kg per hectare, which accounts for 56.5% of the experimental yield) – Adoption of drought and salinity resistant transgenic is projected to bring additional income to farmers, despite an increase in seed cost – The cost of rice seed is projected to be about 15.5% higher than for the existing high yielding varieties and the level of use of other inputs should remain about the same. (Labor, Fertilizer, Pesticide) – Yield of rice would be 25% higher as compared to existing varieties under stress conditions – Farmers would incur INR 7997 per hectare in cost of cultivation, while the total return would be INR 26114 per hectare
2	Selvaraj et al. (2007)	Tobacco streak virus resistant in Groundnut and Sunflower	– Interview with survey questionnaire of 80 groundnut and 30 sunflower growers and 16 scientists from AP, Karnataka and Gujarat – Economic surplus method and cost–benefit analysis	– Adoption of transgenic TSR resistant groundnut would bring 90% higher profits to the farmers despite an increase in the cost of seeds of 20% compared to existing varieties – There would be 8% reduction in labor use due to reduction in application of fungicides – Farmers would incur INR 3573 per hectare in cost of cultivation of TSV resistant groundnut, compared to INR 3651 for existing varieties – Total returns would be INR 38556 per hectare in case of TSVR groundnut, compared to INR 26792 for existing varieties – Adoption of transgenic TSVR sunflower would bring 150% higher profits per hectare despite increase in seed cost of 20%. There would be reduction of labor use of 9% due to 50% reduction in application of fungicides – Yield of TSVR sunflower would be 20% higher than existing varieties such as Ganga Cauvery, Kargil and Suntech 120 – Cultivation of TSVR groundnut and sunflower would bring benefits in terms of high yield, low production cost and high income

(continued)

Table 1.3 (continued)

Sl. no.	Study by	Crop	Sample and methodology	Findings
3	Selvaraj et al. (2007)	Late blight resistant Potato	– Farm survey of 30 potato growers and 4 scientists in CPRI, Shimla – Economic surplus method and cost–benefit analysis	– Yield of LBR potato would be 25% higher, reduced pesticide application costs by INR 1100; reduction in labor use by 11% due to reduced application of fungicides – Farmers would incur INR 73246 per hectare in cost of cultivation of LBR potato, as compared to INT 68893 for existing varieties due to higher seed costs (20% more) for the GM potato, but total returns would be INR 190000 per hectare in case of LBR potato as compared to INR 127000 for existing varieties
4	Krishna and Qaim (2007)	Bt Eggplant (Bt Brinjal)	– Field trial data carried out by Mahyco in several locations (8) in several states – Interviews of 360 Brinjal farmers in three leading Brinjal-producing states in India (AP, WB, and Karnataka) – Consumer surveys (645 households from five locations)	– Bt technology allowed for significant insecticide reductions; amounts of insecticides used against SFB were reduced by 80%, which translated into a 42% reduction in total insecticide quantities – Yields of Bt hybrids were double than those of non-Bt counterparts; yield advantage w.r.t. other popular hybrids and OPVs was even more pronounced – Typical farmer applies 30 insecticide sprays during a single Brinjal crop of 180 days. Repeated application of pesticides results in harmful buildup of residues – With the expected insecticide reductions through Bt Brinjal technology in the Centre/South (35%) and East (48%), health cost savings would be around INR 50/acre and INR 470/acre respectively – The widespread adoption of Bt technology will lead to a decrease in market prices for Brinjal (by 15%). Lower prices, in turn, will lead to higher consumption of Brinjal with positive nutrition effects in low-income consuming households (by 4%)

(continued)

Table 1.3 (continued)

Sl. no.	Study by	Crop	Sample and methodology	Findings
5	Kolady and William (2005)	Bt Eggplant (Bt Brinjal)	– 290 farmer families in 4 districts of Maharashtra – Bivariate probit model	– Use of Bt seeds for controlling the insect's attack is considered to be cost effective compared to chemical alternatives – The conditional probability of adopting Bt hybrid, given that the famer is already adopted hybrid Brinjal is very high at 85%.; whereas there is a negative correlation between past adoption of hybrid and expected adoption of Bt OPV
6	Kumar et al. (2011)	Bt Eggplant (Bt Brinjal)	– Data on production and prices of Brinjal at all-India level and for selected regions covering farmers growing Brinjal in the major states such as West Bengal, Gujarat, Eastern UP and Bihar and Karnataka – Economic surplus method used to estimate potential economic benefits of Bt Brinjal – Economic gains simulated under three adoption scenarios (15%, 30% and 60%)	– Higher yield would accrue due to reduction in crop damage from SFB infestation (yield gain of Bt hybrids was 37.3% over non-Bt hybrids and 54.9% over popular hybrids); reduction in cost due to savings in insecticide use to control SFB (reduction by 41.8%). There will also be better quality of produce which will have better market acceptability and will provide a premium price – Consumers will also benefit from better quality produce which will be free from SFB infestation and residues of chemicals; they will get it at lower rate (3–15% less); and they will have more access to brinjal due to higher production volume – Likely gains for total economy have been estimated between INR 577 crore to INR 2387 crore annually at different adoption level – In terms of regional distribution effects, the major share of welfare gains would accrue in the eastern states (WB, Odisha, Bihar), where most of the brinjal is produced and insect-pest problem is severe – Development of Bt OPV will improve access to resource-poor farmers to technology; who might not adopt more expensive Bt Hybrids due to income constraints

(continued)

Table 1.3 (continued)

Sl. no.	Study by	Crop	Sample and methodology	Findings
7	Krishna and Qaim (2007)	Bt Eggplant (Bt Brinjal)	– Farm survey; 360 brinjal farmers were visited and interviewed in three major brinjal-producing states of India (AP, Karnataka, WB) – Contingent valuation method used to elicit brinjal farmers WTP (willingness to pay) for Bt hybrid seeds	– Considerable reduction in insecticides. The average quality of insecticides used on the Bt plots was 2.82 kg/acre, 45% less than on non-Bt plots – While the mean yield of Bt brinjal was 221 quintal/acre, it was only 102 quintal/acre for the non-Bt counterparts – In Karnataka, 90% of the sampled farmers use hybrid seeds, in AP 38%, while in WB, accounting for more than 25% of the total brinjal area, adoption is less than 1% – The low hybrid adoption in WB is due to the high incidence of bacterial wilt, against which local OPVs are partly more resistant, and a less developed seed marketing network – The farmers mean WTP for Bt hybrids was found to be more than 4 times the current price of conventional hybrids

(continued)

Table 1.3 (continued)

Sl. no.	Study by	Crop	Sample and methodology	Findings
8	Andow (2010)	Bt Eggplant (Bt Brinjal)	– Farm Survey in West Bengal, AP and Karnataka – Economic surplus model	– The agronomic performance and efficacy experiments for hybrid Bt brinjal are designed for large-scale commercial brinjal production systems, and do not reflect the production systems used by small-scale resource-poor farmers. The data are probably appropriate for about 4% of brinjal production in India – Yield gaps are prevalent between experimentally estimated yield and average farmer yield. The yield benefit of hybrid Bt brinjal estimated from the controlled MST and LST experiments should be multiplied by 0.54 to estimate the yield benefit for the average large-scale commercial farmer. This also reduces the estimated benefit to small-scale resource-poor farmers – The expected maximum potential yield benefit from hybrid Bt brinjal is probably $\leq$43.7 q/ha for large-scale commercial farmers and $\leq$7.2 q/ha for small-scale resource-poor farmers; about 16% of the time hybrid Bt brinjal is not expected to out-yield non-Bt brinjal – Insecticide use might decline in large-scale commercial Bt brinjal production systems by an average of 6.5 applications. However, other factors may modulate this substantially, and new secondary pests will result in more insecticide use. It is not possible to estimate how insecticide use might change if Bt brinjal were used by small-scale resource-poor farmers – Hybrid Bt brinjal may improve net returns of large-scale commercial farmers by at most Rs. 23,439/ha and of small-scale resource-poor farmers by at most Rs. 3,250/ha. In comparison, brinjal IPM has improved net returns of small-scale resource-poor farmers by Rs. 66,794/ha – The estimated economic surplus for brinjal IPM is significantly larger than for hybrid Bt brinjal. Farmers are expected to receive 63% of the surplus from brinjal IPM but only 10% of the surplus from hybrid Bt brinjal

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Chapter 2
International Experience in Socio-economic Assessment

Krishna Ravi Srinivas and Amit Kumar

Abstract Countries have implemented Article 26.1 or given effect to SECs in decision-making in multiples ways. About 41 countries have done so with considerable variation. While some have detailed guidelines, some have narrow guidelines. There have been regional initiatives on having a common approach or guidelines. As countries have to ensure that giving effect to Article 26.1 does not violate their obligations and commitments under other international treaties, implementing Article 26.1 is circumscribed by it. While some countries adopt a case by case approach, some have a binding regulation. An issue in studying implementing SEC and SEA among countries is lack of data and case studies. In most cases SEA is limited to grant or denial for approval and doing SEA or taking SEC into account in different stages of the life cycle of LMO is yet to be adopted by countries. While the diversity is understandable and desirable, it is important that there is at least a shared understanding on core elements of SEA, among countries, as otherwise the sheer diversity could result in dilution of SEA. Some suggestions are made for further development of SEA and their adoption.

Keywords SECs · SEA · Regulation · Regional frameworks · Biosafety

2.1 Introduction

It is estimated that only 41 countries have given effect to Article 26.1 through laws/frameworks. Considering the number of countries that have ratified CPB, this number indicates that only about 25% of the members have given effect to Article 26.1. This is a matter of concern and indicates that countries have to be sensitized on adopting SEC in decision-making and make their biosafety/biotechnology regulation compatible with CPB. Although 41 countries have complied with Article 26.1 in one form or other, the diversity in enormous. As discussed elsewhere in this volume there has been no consensus on the core elements of SEC. As CPB does

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not mandate any specific process or rule, the scope for interpretation is very wide. With no standard definition on SEC and model/suggested process and methodology to conduct SEA available, countries have tried many options ranging from making it part of biosafety regulation to consideration on a case to case basis. However with AHTEG's work reaching a crucial stage and its document giving guidelines on the process and suggesting the core elements in SEC, it is possible for countries to rely on this and/or calibrate their regulations accordingly. In this volume we have proposed Guidelines Framework and methodologies. In this chapter we take that to the next step by suggesting how SEC can be conducted at different stages of the life cycle of the LMO.

The objective of this chapter is not to discuss in detail the provisions of different countries or to review them in detail, country by country. Rather we provide an over view of the current position in implementation and give few examples to highlight what has been done. Further we make few suggestions, identify what needs to be done and propose a way forward.

2.2 Implantation: Experiences, Issues, and Challenges

Table 2.1 lists countries that have SEC related legislations or frameworks. But this does not mean that all of them have implemented them or in the process of implementing them. As pointed out elsewhere in this volume, in the past two decades or so, capacity building exercises have been undertaken in different countries, particularly developing countries and LDCs, by inter alia, FAO, UNEP, and UNIDO. This has resulted in better capacity in biosafety and setting up of biosafety regulations. It is likely that frameworks have been included or established as part of these regulations. Doing SEA and taking SECs in consideration for decision-making is also often considered as part of biosafety guidelines.

Table 2.1 Countries having SECs-related Legislations/Framework

Africa	Americas and Caribbean	Asia-Pacific and Oceania	Europe
Burkina Faso	Argentina	Australia	Austria
Cameroon	Belize	Indonesia	France
Ethiopia	Brazil	Malaysia	Italy
Ghana	Canada	New Zealand	Latvia
Kenya	Colombia	Philippines	Norway
Madagascar	Costa Rica	Republic of Korea	
Mali	Cuba		
Mauritius	Honduras		

(continued)

Table 2.1 (continued)

Africa	Americas and Caribbean	Asia-Pacific and Oceania	Europe
Namibia	Mexico		
Nigeria	Panama		
Senegal	Peru		
South Africa	Saint Kitts and Nevis		
Tanzania	Uruguay		
Togo	Venezuela		
Zambia			
Zimbabwe			

Source Compilation by author based on various sources viz. UNEP CBD BCH documents, Chaturvedi et al. (2012), Falck-Zepeda and Zambrano (2011), Benimelis and Myhr (2016)

Of the total of 41 countries, 16 countries are from Africa followed by 14 American and Caribbean countries; 6 Asia-Pacific and Oceania countries and 5 European countries (Table 2.1). The number of countries in Europe is less for obvious reasons while the Norwegian approach as elucidated in the Gene Act.

From the analysis of the provisions within the dimensions enumerated by the AHTEG-SEC, the following socio-economic issues have taken into account within the legal or institutional frameworks of the countries (Table 2.2).

This does not mean that all the countries have incorporated them or used them in decision-making. While there are definitional and methodological issues in them, many of them can be measured objectively while some like ethical and moral concerns have to be value based or take into account the cultural aspects. These cannot be ignored, as impacts on biodiversity and traditional communities have to be considered.

However for law making and regulation, it is better to identify the range of SECs than to make it a very open list. A survey by UNEP identified the range of SECs to be wide, from food security to gender, from cultural aspects to intellectual property rights. But when it comes to identifying them on the basis of priority it was clear that among them, five ("food security, health-related impacts, coexistence of living modified organisms, impacts on market access, and compliance with biosafety measures") were considered more important. This is explained in the Table 2.3.

However, there is no empirical data to verify this. Because it is not necessary that a decision on LMO/GMO should always be related to SEC while SEC may or may not be one of the factors that were considered. When a decision is to be taken primarily or purely on the basis of scientific evidence and technical factors, there might not be a need to consider SEC or the regulatory mechanism/biosafety regime might need SEC as an additional factor to be considered only if clearance from scientific and technical angle was given. If decision-making is done on the basis of a policy process that was not part of any regulatory mechanism then it would be difficult to attribute a SEC as a factor or the cause. In most cases the approval to

Table 2.2 **SEC**s taken into account in Biosafety decision-making

Social dimension • Social acceptability • Social utility • Changes in land use • Changes in communities' rights • Distribution of benefits with future generations • Equity issues • Food sovereignty • Food security • Gender impacts • IPRs and patents • Livelihood of communities • Sustainable development	*Economic dimension* • Access and cost for GM technology • Changes in agricultural production systems • Changes in agricultural productivity • Changes in small and marginal farmers income • Change in export trends • Change in economic value of traditional varieties • Change in industrialization trends • Change in traditional markets • Crop loss • Employment loss/gain • Impact on small business development • Impact on organic agriculture
Cultural/ethical/religious dimension • Cultural aspects and practices • Erosion of indigenous technology and knowledge • Ethical and moral concerns • Impact on traditional crops and products • Religious concerns • Traceability and labeling issue	*Ecological-related dimension* • Loss of genetic diversity • Agro-diversity loss • Farmers' varieties loss • Development of weed resistance • Changes in energy use patterns • Changes in herbicide use • Changes in insecticide use • Greenhouse gas emission • Soil contamination/erosion • Impact on environment
Health dimension • Food safety • Nutritional needs • Public health impact	

Source Chaturvedi et al. (2012), Binimelis and Myhr (2016)

commercialize includes economic assessment in terms of increase in yield and that to a great extent justifies the economic rationale for approval. But when other factors are considered, the decision could be mixed and the other factors could be used to override the decision based on economic criteria. Racovita (2011) lists the following as examples:

(1) In 2002 Zambia rejected food aid containing GM maize despite famine on the ground hat risks were not well understood. If there was any genetic contamination, the exports to Europe would be affected.
(2) In 2009 Hawaii prohibited genetic modification of Hawaiian Taro as that variety was considered as an ancestor of the Hawaiian people.

She also points out that Argentina has specified that approval for GMOs should take into account the impact on exports of Argentina. This is understandable as not all countries allow import of GM crops and products derived from them for use in all purposes. Some countries allow GM food only for feed purposes and not for use as

Table 2.3 Socio-economic issues that can be taken into account in reference countries' decision-making compared with ratings of the importance of socio-economic issues in decision-making

#	Socio-economic issues that can be taken into account in reference countries' decision-making systems for LMOs (Q10)	Importance of socio-economic issues considered in LMO decision-making (Q15)	
		Method I:ranking system	Method II: scoring system
1	Food security	Food security	Health-related impacts
2	Impacts on market access	Health-related impacts	Coexistence of LMOs
3	Health-related impacts	Coexistence of LMOs	Food security
4	Compliance with biosafety measures	Impacts on market access	Impact on market access
5	Coexistence of LMOs	Compliance with biosafety measures	Compliance with biosafety measures
6	Impacts on biodiversity	Impacts on biodiversity	Macroeconomic impacts
7	Farmers' rights	Economic impacts of changes in pest prevalence	Economic impacts of changes in pest prevalence
8	Economic impacts of changes in pest prevalence	Macroeconomic impacts	Impacts on biodiversity
9	IPRs	Farmers' rights	Impacts on consumer choice
10	Indigenous and local communities	IPRs	Use of pesticides and herbicides

Source UNEP (2010), p. 5

food for humans. On the other hand there are countries that do not permit cultivation of GM crops, but permit import of GM foods for limited purposes. Thus many concerns, ranging from biosafety to trade impact the decision-making on GMO/LMO and SEC is one of them.

While pointing out that there is strong consensus on including SEC in decision-making, UNEP states

> A number of conclusions can be drawn from the above information. First, socio-economic considerations can be taken into account in the decision-making process concerning living modified organisms if countries want to do so. Second, once countries start to incorporate socio-economic considerations in their decision-making process they can do this across decisions, across multiple organisms and across intended uses of the organism. The survey results also suggest that the current practice for including socio-economic considerations in decision-making for a majority of the reference countries was for one entity to assess the socio-economic considerations and a different entity to evaluate the assessment. Three entities, the National Competent Authority, a multi-sectoral committee and a government committee consisting of several departments, are most often involved in the assessment of socio-economic considerations and the evaluation of the assessment. (UNEP 2010 p 13)

Broadly speaking, we can classify countries that have rules and regulations, into two categories. First category of countries are the ones who have taken a very broad idea of SEA and SEC while defining elements of SECs and the processes, while the second category of countries are the ones that have taken a rather limited or narrow position on SECs.

Countries such as Norway, Ethiopia, Mali, Nigeria, Senegal, Togo Tanzania, Zambia and, Cameroon, are in the first category of countries, while countries such as Argentina, Mexico, Zimbabwe, New Zealand, Australia, and Canada would come under the second category. However, such categorization is not helpful beyond a point because there is no uniformity in definitions, parameters, processes and scope of SECs.

Norway has a very comprehensive definition of SECs for incorporation into decision-making process. The Norwegian Gene Technology Act has provisions that mandate that the production and use of LMOs take place in an ethical and socially justifiable way, in harmony with the principle of sustainable development and without detrimental effects on health and the environment. Some countries in Africa also have such provisions in the decision-making process. For example in Ethiopia, there is a constitutional provision that require that health, environmental well-being and the general socio-economic conditions of the country be protected from risks that may arise from modified organisms. But the larger question is how effective such provisions are and whether they are the correct models for developing countries and LDCs.

There are regional frameworks that help in incorporation of socio-economic considerations in the decision-making. The EC Directive 90/220/EEC provides for an approval process and labeling and packing requirements for all GM food, which aims to avoid the adverse effects on human health and the environment that could result from a release of LMOs into the environment or food chain. The African Union and the Andean Community provide regional approaches for the socio- economic analysis. For example, Article 1 of the African Model Law on Biosafety specifies that the objective of this model law is to contribute to ensuring an adequate level of safety for the protection of biological diversity, human and animal health, socio-economic conditions and ethical values in the making, safe transfer, handling and use of genetically modified organisms and products of genetically modified organisms resulting from modern biotechnology. Socio- economic conditions are defined as "the economic, social or cultural conditions, livelihoods, knowledge, innovations, practices and technologies of indigenous and local communities including the national economy." Although there are such similarities, the adoption of GMO/LMO in Europe and Africa are different, By and large, European countries have *de facto* moratorium on cultivation of GM crops, whereas in Africa the situation is different. Some countries have adopted GMOs in agriculture while some are trying to. But whether using SECs to deny adopting GMOs in agriculture is a good decision or not, is a different issue.

The New Partnership for Africa's Development (NEPAD) has launched the African Biosafety Network of Expertise (ABNE) through its African Biosciences Initiative in Africa. The main objective of ABNE is the provision of biosafety resources for African regulators in decision-making on safe use, deployment and management of biotech products that are locally developed, imported, and adopted in Africa.[1]

The Andean Community's (composed of five countries, namely Bolivia, Colombia, Ecuador, Peru and Venezuela) Regional Biosafety Strategy adopted in 2002 does not override the existing laws.[2] The Regional Biosafety Strategy does consider socio- economic considerations that may be adopted by member countries that are developing their own laws and regulations although it does not provide any guidance on implementation.[3]

There are not many case studies on implementation of the Regional Frameworks or for that matter on national experiences and tell us how well the Regional Frameworks have been adopted or incorporated. There are limitations in understanding implementation solely on the basis of the texts. Because only a case study based on implementation in a broader context, examining the institutional interplay and how the implementation is facilitated or constrained by other factors will enable us to understand the effectiveness of SECs and whether they have helped in or contributed to decision-making.

In a recent article, Beumer compares and contrasts how Kenya and South Africa have included SEC in decision-making. According to her while Kenya has adopted a bottoms up process before assessing the technologies and gives a strong emphasis on scientific expertise, South Africa gives less importance to scientific evidence, and applies a case to case basis, with standards being established in an adhoc basis (Beumer 2019) She points out the fundamental difference lies in framing the regulation of risks and SECs, with an approach based on Sanitary and Phytosanitary (SPS) measures, the traditional frame is science based while for the one based on SEC, it is politics based. She finds that these two are potential pathways for including SEC in decision-making. According to her "Identifying these two models for including socio-economic considerations into biotechnology decision-making is therefore both relevant and timely. Many countries currently intend to take into account SECs but struggle to implement it as detailed information about practical experiences with SECs in biotechnology regulation are absent. It should be clear that the two models for solving this problem presented in this article are shaped by the local contexts of Kenya and South Africa and therefore cannot unproblematically be copy-pasted to other countries." (page not mentioned as this is a forthcoming article).

In our view such case studies that go into details of decision-making and the processes and factors that are part of the regulatory processes are important as they tell us what is gained and lost in translating SECs in practice and how local contexts play an important role in designing and implementing SECs. At the same time to consider that the approach based on SPS is purely technical while the one based on SEC is purely political is misleading as it sets two extremes (technical and political)

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[1]See also Summary of On-Line discussions held in 2013 in https://www.cbd.int/doc/meetings/bs/bs-ahteg-sec-01/information/-sec-01-inf-01-en.pdf.

[2]Chaturvedi et al. (2012).

[3]Chaturvedi et al. (2012).

as the basis, ignoring how values, norms, institutional practices impact both.[4] While we agree with the view, that these two cannot be copy-pasted to other countries and adopted, it is also true that both models may undergo changes over years and only experience over years can tell us as to whether the initial description holds.

The only major study that has examined how countries interpret and enshrine SECs in decision-making on various parameters/factors, taking into account the texts/rules points out "The review reveals that there are significant differences in how socio-economic considerations are integrated into and assessed in the studied national normative frameworks. The main differences are related to the status of the regulations and approach used (prescriptive versus descriptive formulations of what socio-economic considerations refer to, the inclusion of only risks versus assessments integrating both risks and benefits, or assessments taking only into account direct effects versus the ones that also integrate the assessment of the co-technologies used in conjunction with the GM crop)….. A second interesting feature is the wide inclusion of health and environmental-related considerations as part of the socio-economic assessment, and the integration of socio-economic aspects in the definition of "environment" in a significant number of the analysed countries, blurring the separation between these dimensions that is traditionally demarcated by the risk assessment (Benimelis and Myhr 2016, p. 18).

In our views these two are very important findings and deserve to be explored further. However we do not consider their positive review and recommendation on the Norwegian Gene Act. We consider that while it is relevant for Norway, an European country which ranks high in Human Development Index and without any major issue in food security, it cannot be used as a model for developing countries and LDCs. One reason is that the broad interpretation given in that Act for SEC and the very broad definition on environment make it difficult to adopt. For developing countries and LDCs often the need is to strike a balance among competing objectives, and, to ensure that biosafety regulation and SEC are harmonized to meet their national goals. We are not suggesting that in the name of science based assessment and a purely technocratic view on regulation, SEC should be relegated or given not much importance. Rather we suggest that in the name of SEC, the decision-making processes and procedures should not be taking into account all possible factors, making the exercises elaborate and time consuming and unaffordable. On the other hand, we agree that there should be more stakeholder participation and long term concerns should be addressed. As both Beumer, and, Benimelis and Myhr point out regulation for SEC is a learning process and will continue to evolve over a period of time. Having said that, it is worth pointing out that the evolution of the regulation in future may be impacted by factors that are not taken into account to day or some factors may gain more prominence in future than now, particularly in case of applications like Gene Drives, and, gene edited crops.

[4]See also Racovita (2017).

2.3 Suggestions and Way Forward

On the basis of our analysis, we make the following suggestions:

(1) There is an urgent need for comprehensive studies in implementation, covering all aspects and taking into account the institutional interplays, values, norms as well as risk assessment practices and principles. Such studies should examine cases where SEC have been used as well as cases where SEC could have been used but not used.
(2) From such studies a set of best practices and guidelines can be developed also indicating the cautions that are necessary.
(3) While we do not think one model or law fits all will work, there is a need to have a model law with definitions, based on a risk assessment model so that it can indicate what can be the essential elements in any law on SEC and how the difficulties in defining and identifying SEC can be overcome. Obviously our suggestion here is not to use any national legislation as a forerunner for such a model law or use that and adapt it to develop a model law. Rather this should be a new exercise based on principles on SEC, taking into account the lessons from implementation and suggestions of AHTEG.
(4) While the literature on SEC and SEA is evolving not much attention is being paid to SEC and SEA at different stages in the life cycle of LMO. There is a need to consider them as suggested by Chaturvedi et al. (2012). We think this will be all the more true in case of applications like Gene Drives, if SEA were to be done for them.
(5) The research on SEA and SEC can benefit from studies in other disciplines and inter-disciplinary research on impact analysis, new approaches like Social License to Operate and from insights in STS (Science Technology Studies). So we suggest that CBD or UNEP should launch a research program on SEC that can address the current issues and emerging issues in SEA and SEC.

The way forward in implementation of SEA and SEC is likely to be impacted by the work of AHTEG and how discussions in COP-MOP evolve. As the next COP-MOP is due next year it is hoped that it will facilitate the work of AHTEG further by launching a three year program on SEA and SEC so that the work of AHTEG could be taken forward in a better way. The program can benefit from the discussions and debates in CBD and elsewhere on emerging technologies and applications. It should help in identifying the factors that can help in harmonizing principles for SEA and SEC in implementation and help in development of laws and rules that give effect to implementing Article 26.1 in letter and spirit.

2.4 Conclusion

One obvious lesson from the implementation of SEC is that nations have followed different approaches and have contextualized both to suit their needs. But whether these have resulted in effective implementation of SEC or fuller realization of objectives of Article 26.1 is to be investigated as there are not many case studies on implementation. Similarly more work on theoretical aspects of SEA and SEC are required. There is a lot to do in theory and practice on implementing Article 26.1 and work of AHTEG should be taken forward, preferably by launching a program on SEA and SEC under the auspices of CPB.

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Chapter 3
Cost–Benefit Analysis of Potential Living Modified Crops

P. G. Chengappa and A. V. Manjunatha

Abstract Recognizing the important role biotechnology plays in promoting human well-being, particularly for food security and agriculture livelihoods, the Cartagena Protocol on Bio-safety provides that parties take socio-economic considerations into account in decision-making on Living Modified (Genetically Modified) Organisms (LMOs). The chapter is an attempt to consolidate efforts towards building a framework for such analysis in India. It provides an overview of the methodology and analytical methods applied in the six studies to estimate costs and benefits of cultivating potential LMO crop/s. The major economic considerations—yield, net returns and labour requirements are calculated based on the assumption of the introducing traits to these crops under study. The findings from the Cost–Benefit Analysis (CBA) are highlighted and summarized. In addition, certain social dimensions that are essential for a holistic socio-economic assessment have been aggregated using qualitative methods for assessing perceptions and attitudes of stakeholders on aspects related to health and environment. The six studies have provided a glimpse into a cross-cutting and socio-economic assessment and paves the way for a robust interdisciplinary socio-economic assessment that include CBA with sensitivity analysis, quantitative participatory approaches and choice-based experiments of LMOs in India's regionally diverse milieu.

Keywords LMO · GM technology · Socio-economic assessment · India · CBA

3.1 Introduction

Socio-economic implications are considered vital as agriculture is the mainstay of a majority of livelihoods in India. Heeding to such issues in the Indian context, Article 26.1 of the Cartagena Protocol on Bio-safety provides that parties may take

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socio-economic considerations into account in decision-making on Living Modified (Genetically Modified) Organisms (LMOs). Given this protocol, there is a dire need for a comprehensive understanding of socio-economic issues relevant for living modified organisms and to suggest a methodological framework for socio-economic assessment. This far, in India, the guidelines and methodologies for socio-economic evaluation of LMOs for cultivation and entry into the food chain of animals/humans has not been developed and intensively tested.

Towards this end, Cost–Benefit analysis has a long history in project assessment and evaluation. It explicitly quantifies and monetizes all the costs and benefits of an intervention and facilitates systematic consideration of the various factors that influence strategic choices (Dasgupta and Pearce 1972; Ray 1984; Boardman 2004; Quah and Haldane 2007). It can be an expensive and cumbersome task, depending on the range of input data used to determine the costs and benefits. As such, it is recommended for use in projects where the potential costs are significant enough to justify the allocation of resources to forecast, measure and evaluate anticipated benefits, costs and impacts. Among the various CBA (Cost–Benefit Analysis) criteria such as Benefit Cost Ratio, Incremental Cost–Benefit ratio, payback period, the most effective criterion for evaluation is B/C, indicating that the higher the benefit cost ratio, the more profitable the technology. Taking time into consideration, technology evaluation requires discounting of future benefits and costs as society prefers the present to the future. Given this, the methods developed include discounted Net Present Value (NPV), Internal Rate of Return (IRR) and social rate of discount. The former method states that as NPV falls, the discount rate increases and at a certain point the NPV becomes negative. The rate at which NPV changes from positive to negative is the IRR that must be higher than its discount rate. NPV criterion is commonly used for project/technology evaluation in private and public sectors. But the NPV criterion is technically superior. As the calculated benefits and costs of a project may vary depending on differing assumptions related to the data and methodology applied in the Cost–Benefit analysis. The range of potential outcomes for differing inputs is gauged using a sensitivity analysis. However, there are certain limitations arising from difficulties in cost and benefit assessment such as arbitrary discount rate, unaccounted opportunity cost, externalities, joint costs and benefits and adjustments for risk and uncertainty.

In addition, a social Cost–Benefit analysis captures the difference between the total net present value of benefits and costs by assigning monetary values that reflect society's willingness to pay to obtain benefits or avoid changes (costs). Its point of departure is that fact that it takes social welfare into consideration by going beyond commercial profitability to include social profitability. This may be arrived at in three steps namely; an objective function followed by obtaining social measures of the unit values of inputs and outputs, most commonly referred to as shadow prices to calculate the social cost and benefits in each year and finally a decision criterion to reduce the stream of social costs and benefits into an index. This index would then be used to select or reject or rank a project/technology relative to some other project/technology. However, this method was not considered due to data constraints on assessing the social costs and benefits of LMOs. Therefore, the studies in this book have operationalized the Economic Cost–Benefit Analysis.

3.2 Data and Methodology

The Ministry of Environment and Forests (MoEF&CC) funded a research project on socio-economic impacts of LMOs that was coordinated by Research and Information System for Developing Countries (RIS), Government of India, in association with six selected institutions and Universities. These studies involved validating questionnaires, conducting field survey, organizing and participating in workshops and development of guidelines and methodologies for socio-economic assessment of LMOs for selected crops. To develop such a policy document on socio-economic assessment for the Cartagena Protocol, particular crops and traits were selected for India. Among these crops, Bt Cotton is the only LMO, commonly known in India as a GM crop variety (hereafter used synonymously with LMO) that has been approved for cultivation in the country. The comparative cost and benefit analysis of other crops have been undertaken to assess the perceptions and attitudes of farmers based on various hypothetical scenarios related to changes in yield, desired traits, seed costs as well as their views on its health and environmental impacts.

All six studies have conducted primary surveys to analyse two crops and two traits. The Table 3.1 indicates the study area, crops, traits and sampling design undertaken in the respective studies. To achieve the objectives of the studies, the required primary data were collected from all the sample stakeholders by personal interview method with the help of pre-tested and structured schedule with three distinct parts viz., General information, Trait related information and perception about the LMOs as developed by the partner institutions. The questionnaire specifically included socio-economic status, land holding, cropping pattern trait related information on seed, pest, disease, weed management and perception of farmers on GM crops. In addition, the cost of production of crops, expenses on seeds, manure and chemical fertilizers, plant protection chemicals, bullock labour (both hired and owned), machine power, human labour (both hired and family labour), marketing costs and irrigation cost were also obtained. For computing the returns, the gross value of the output per farm from crop was calculated by multiplying production with the post-harvest price realized by the farmer. Net value of output was computed by deducting total costs with the gross value of output. In addition, qualitative techniques were also used to understand the perceptions of these farmers. It is important to understand attitudes of farmers towards GM crops as it is a complex issue that involves the interplay between many factors. These factors include concerns about biotechnology, confidence in regulation, societal values, moral aspects, and attitude to labelling among others.

3.2.1 Analytical Method

All investment made in developing the LMO, licencing fee, land, building, irrigation structure and machinery at market/current value are amortized based on the life span of the asset. We may use the depreciation on these investments to arrive at the investment cost per each year.

Table 3.1 Overview of six studies and sampling methods

Researcher/author	Institute	State	Crop	Trait	Sample design	Total sample size	Control sample
Padaria (2016)	Indian Agricultural Research Institute, New Delhi (IARI)	Punjab	Wheat	Herbicide tolerance	Multistage sampling	220	–
		Haryana	Mustard	Insect (Aphid) resistance			
Ashok et al. (2016)	Tamil Nadu Agricultural University, Coimbatore (TNAU)	Tamil Nadu	Maize	Insect resistance	Random sampling	120	–
			Brinjal	Herbicide tolerance			
Lalitha (2016)	Gujarat Institute of Development Research (GIDR)	Gujarat	Ground nut	Drought tolerance	Random sampling	203	–
			Castor	Salinity resistance			
Patil (2016)	University of Agricultural Sciences, Raichur (UAS, Raichur)	Karnataka	Bt Cotton	Insect resistance	Purposive multistage random sampling	250	*Non-BT Cotton* Research field data
			Pigeon Pea				
Srinivas et al. (2016)	National Academy of Agricultural Research Management, Hyderabad (NAARM)	Telangana	Brinjal	Tolerance and resistance against abiotic and biotic stresses	Multistage sampling Simple random	250	–
			Maize				
Manjunatha (2016)	Institute for Social and Economic Change, Bengaluru (ISEC)	Karnataka	Aerobic rice	Drought tolerance	Random sampling	50	32 Conventional Rice
			Bt Cotton	Insect resistance		100	–

Note: Compiled by authors; based on reports submitted by six partner institutions to RIS, New Delhi

All working cost incurred at market prices each year such as cost on seed, fertiliser, plant protection chemicals, labour, maintenance of machinery and cost incurred on borrowing money and sale of produce are considered. The return realized by sale of produce at market prices is considered as benefits. By making of costs and benefits a flow stream of costs and returns for each year is arrived and are discounted to work out the C:B ratio.

Padaria (2016) from IARI, in particular adopted highly qualitative approach involving stakeholders' workshop and focus group discussions representing scientific community, farmers, social activists and social groups, media groups, traders, seed companies and extension professionals a narrative was prepared. The analysis was undertaken using preference ranking method to construct a matrix of decision-making criteria, Likert scale and semantic mapping for risk perceptions among farmers and a conjoint analysis for consumers' preference assessment.

While, Ashok et al. (2016) study encompassed an economic assessment using trait valuation in an ex-ante situation as well as a partial budget analysis for contemplated changes for the respective crops under study followed by a sensitivity analysis. The study by Lalitha (2016) from GIDR, particularly concentrated on benefit–cost ratios and alternate benefit cost scenarios of increase in price and yield to discuss the adoption of trait related seeds by farmers. The quantitative assessment by Patil (2016) UAS, Raichur applied tabular formats using averages to estimate and compare economic characteristics of the crops under study along with a modified Cobb-Douglas production function in log-linear form and Garrett Ranking. The analytical methodology followed by Srinivas et al. (2016) from NAARM, apart from tabular formats used a probit model to understand the ex-ante adoption of LMOs by farmers. The study undertaken by Manjunatha (2016) from ISEC analysed the performance of the two crops using the Cost–Benefit analysis, which included social considerations and ranking technique in the assessment. The gross margins were computed by including irrigation cost (amortized cost technique at 3% real interest rate) for Bt cotton and irrigation charges per season for Aerobic rice.

3.3 Synoptic Economic Assessment

This section summarily discusses the costs, yields, returns, area and labour of the respective crops based on cost of cultivation, yield, and net returns.

Ashok et al. (2016) found that Tamil Nadu farmers growing improved varieties of maize with resistance to insects and tolerance to herbicides realised net returns to the extent of Rs. 26,966 and Rs. 38,434 in Kharif and Rabi respectively. The net economic benefit due to improved maize (GM), varied from Rs. 5028 to Rs. 13,705 per hectare in kharif season and from Rs. 5549 to Rs. 15,410 in Rabi season with an assumed yield increase from 5 to 15 and a 20% increase in seed cost. While in Telangana, Srinivas et al. (2016) found that GM maize with preferred trait would bring in 34.88% higher net return compared to the non LMO maize as shown in Table 3.2.

Table 3.2 Cost and benefit analysis per hectare

Author/researcher	Crop	Season	Type	Yield (Qtls)	Cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)
Ashok et al. (2016)	Maize	Kharif		77.75	59,803	86,769	26,966
		Rabi		80.50	60,179	98,613	38,434
	Brinjal	Kharif	Local	175.90	3,97,784	5,98,411	2,00,627
			Hybrid	469.20	4,42,264	7,87,317	1,29,906
		Rabi	Local	189.00	3,98,159	5,28,066	1,29,906
			Hybrid	521.60	4,45,969	7,41,715	2,95,745
Lalitha (2016)	Castor			23.20	46,615	–	52,151
	Groundnut			15.20	56,833	–	66,908
Patil (2016)	Cotton		Bt	28.075	81,738	1,12,870	31,132
			Non-bt	18.75	71,228	84,375	13,146
	Pigeon pea			11.175	49,614	58,280	8665
Srinivas et al. (2016)	Brinjal			517.00	91,188	4,08,750	3,17,562
	Maize			33.26	28,966	40,800	11,834
Manjunatha (2016)	Rice	Kharif	Aerobic	21.39	46,287	67,917	21,630
			Conventional	20.40	16,552	25,625	22,682
		Rabi	Aerobic	20.51	46,762	64,897	18,135
			Conventional	19.46	17,896	26,096	20,500
	Bt cotton			21.87	52,532	94,555	42,022
Padaria (2016)	Mustard			7.04	9752	24,633	14,881
	Wheat			19.91	10,443	30,356	19,913

Note: Compiled by authors; based on reports submitted by six partner institutions to RIS, New Delhi

In Brinjal, the genetic modification/trait is insect resistance against the pest shoot and fruit borer. Farmers in Tamil Nadu cultivate both local varieties of Brinjal and hybrids. The net return from the GM Brinjal is Rs. 2,00,627 from local and Rs. 1,29,906 from hybrid varieties in kharif season. Whereas in Rabi season it was Rs. 1,29,906 from local and Rs. 2,95,745 from hybrid varieties. The economic benefit due to improved brinjal variety and brinjal hybrid with insect resistance was estimated separately as the input use, yield and profit vary widely between local variety and hybrid. The increase in income due to improved brinjal variety with insect resistance varied from Rs. 63,668 to Rs. 1,23,509 per hectare in kharif season and from Rs. 64,441 to Rs. 1,17,247 in Rabi season with an assumed yield increase from 5 to 15 and 20% increase in seed cost. In the case of brinjal hybrids, the net change in income per hectare due to insect resistance trait varied from Rs. 72,653 to Rs. 1,51,385 in Kharif season and Rs. 74,666 to Rs. 1,48,838 in Rabi season with an assumed yield increase from 5 to 15 and 20% increase in seed cost. A similar study by Srinivas et al. (2016), on Brinjal in Telangana has revealed that the net return from non-bt brinjal crop was Rs. 3,17,562. However, if the Bt brinjal crop with preferred trait was grown it would increase the net return by 7.34% compared to non-bt brinjal. Further analysis of Table 3.2 reveals that the study by Lalitha (2016) in Gujarat on castor and groundnut estimated that the net return from a hectare of castor was Rs. 52,151 where as in case of groundnut it was Rs. 66,908.

In the study conducted across the districts of Hyderabad-Karnataka region by Patil (2016), the economics of Bt cotton of farmer's field was compared with the economics of Bt cotton from a research field and the traditional crop of the region i.e. pigeon pea. The results showed that the net return realised from the non Bt cotton was just 42% (Rs. 13,146) of the net return realised from Bt cotton (Rs. 31,132). And when compared to pigeon pea, the net return from Bt cotton was almost 3.5 times higher. The reason for higher net return in case of Bt cotton was mainly due to higher yield compared to non Bt cotton and pigeon pea crops. Returns per rupee of investment were higher in case of Bt cotton crop (1.38) compared to Pigeon pea (1.17) and non-Bt cotton crop (1.18). However, the study by Manjunatha (2016), has shown that the net return in case of Bt cotton of the current study was almost double as compared to non Bt cotton results of some of the previous studies. In the same study, aerobic rice was compared with conventional rice for drought resistance trait, and the results showed that the difference in net return was insignificant.

According to the study conducted in Punjab and Haryana by Padaria (2016), the insect resistance trait in mustard will reap net return to the extent of Rs. 14,881 per hectare which is almost the double of non-GM mustard in the hypothetical scenario. Similarly, in wheat with the herbicide tolerance trait, a farmer would release a 15% increase in the net returns.

The cropping pattern from Ashok et al. (2016) study shows that the gross cropped area of maize farmers was 8.91 ha of which around 60% was allotted to maize during kharif and 67% in Rabi season. Among the Brinjal sample households, the gross cropped area was 12.26 ha out of which around 18% during kharif and 26% during rabi was allotted to brinjal. In both the cases, the maize and brinjal occupied major portion of cropping pattern respectively.

In a study by Lalitha (2016), castor farmers from Gujarat allotted around 26% of their land to castor and it was restricted to kharif only whereas groundnut farmers grew groundnut in both kharif and summer to the extent of 25% and 0.80% of the GCA respectively. A study by Patil (2016) shows that farmers in Hyderabad—Karnataka region allotted 44% of their GCA to cotton and 28% to that region's traditional crop pigeon pea. This shows that cotton was major crop among sample farmers followed by pigeon pea. Among Brinjal farmers from Telangana, the average total land holding was 1.75 ha and maize farmer was 1.71 ha. Brinjal is on an average of 13% of their GCA and maize is cultivated to the extent of 60%. From the study by Manjunatha (2016), farmers who practiced aerobic method of rice cultivation, the area allotted to aerobic method was higher during kharif (62.68%) compared to conventional rice (23.27%) whereas in Rabi season it was the opposite, where aerobic covered 29.27% and conventional, 71% of the total GCA (Table 3.3).

The labour use pattern from the study by Ashok et al. (2016) shows that maize requires around 117 man days for cultivation, whereas in case of brinjal among two types of varieties considered hybrid required more labour compared to the local variety in both Kharif and Rabi seasons. The study in Gujarat by Lalitha (2016) estimated labour requirements for a hectare of castor and groundnut cultivated at

Table 3.3 Percentage area under each selected crop in different seasons in 2014–15 (% to the total cropped area)

Author/researcher	Crop	Seasons	Percentage	Gross cropped area (GCA) in Ha
Ashok et al. (2016)	Maize	Kharif	59.81	8.91
		Rabi	66.81	8.91
	Brinjal	Kharif	18.47	12.26
		Rabi	25.67	12.26
Lalitha (2016)	Castor	Kharif	25.90	5.73
	Groundnut	Kharif	24.50	5.73
		Summer	0.80	5.73
Patil (2016)	Cotton		44.46	19.00
	Pigeon pea		27.88	19.00
Srinivas et al. (2016)	Brinjal		13.14	19.00
	Maize		60.23	19.00
Manjunatha (2016)	Aerobic rice	Kharif	62.68	3.39
		Rabi	29.27	3.39
	Bt cotton		54.36	12.40

Note: Compiled by authors; based on reports submitted by six partner institutions to RIS, New Delhi

148 and 137 man days respectively. While, Patil (2016) compared the labour use between Bt cotton, non-Bt cotton and pigeon pea and found that on an average, the farmers engaged more labour (56.21 man days) in cultivation of Bt cotton crop followed by non-*Bt* cotton crop (49.48 man days) and pigeon pea (25.23 man days).

Major variations in labour requirement were found in harvesting and transportation between Bt and non Bt cotton crop. Labour use in the cultivation of aerobic rice and conventional rice showed that during kharif season, both varieties of rice were cultivated with a similar number of man days. However, during Rabi, the conventional method of rice cultivation used much less (almost half) labour as compared to aerobic method of rice cultivation (Table 3.4).

3.4 Social Dimensions

The studies this far have shown that the various methods used to undertake a Cost–Benefit analysis have yielded a positive result in the simulated scenarios for farmers cultivating the respective crops.

In this chapter, apart from the economic Cost–Benefit analysis that was a common analytical tool for the studies as most information on these indicators were provided an exploratory analysis of the social aspects was possible especially from the

Table 3.4 Labour use pattern in cultivation of LMO crop

Author/researcher	Crop	Seasons	Total labour
Ashok et al. (2016)	Maize		117
	Local Brinjal	Kharif	1176
		Rabi	1171
	Hybrid Brinjal	Kharif	1210
		Rabi	1196
Lalitha (2016)	Castor		148
	Groundnut		137
Patil (2016)	Bt Cotton		56.21
	Non Bt Cotton		49.48
	Pigeon pea		25.23
Manjunatha (2016)	Aerobic rice	Kharif	46
		Rabi	65
	Conventional	Kharif	45
		Rabi	37
	Bt cotton		39

Note: Compiled by authors; based on reports submitted by six partners

Padaria's (2016) qualitative assessment. The findings of this study help in insightful inferencing such as farmers may have expressed willingness to adopt the transgenic crops; however, the perception among the other stakeholders was varied. Farmers in these studies also opine that they are prepared to adopt new technologies that would enhance profitability and reduce labour requirements as long as they are assured that the government takes all environmental safety precautions. As farmers were unaware of the adverse effects of GM crops on human, livestock and environment cited by Ashok et al. (2016). Lalitha (2016) indicated that there is scope for introducing LMOs in castor and ground nut as indicated by the farmers' willingness to adopt them. While this is a positive indication, there are also fears about the scientific information about GMOs. This signals that there is a need for the scientists to communicate frequently to the farmers about the LMOs. However, further insights on issues related to legal, ethics and governance, social implication of risks, risk–benefit analysis and social Cost–Benefit analysis are areas for further research to wholly make an assessment of the socio-economic considerations in adoption of transgenic or living modified organisms.

Therefore, it is evident that qualitative techniques must be used to complement the quantitative techniques. Some of these social attributes have been gleaned from the respective studies and highlighted under the following sub-sections.

3.4.1 Gender

We next examine employment effects by gender. A case in point is brinjal cultivation, where the total employment in hybrid cultivation is similar to that in variety cultivation (Ashok et al. 2016). However, employment of women was higher by 7.5% in hybrid cultivation, whereas employment of men decreases by 12%. Most of this additional employment were hired female labour and not women from the family. As far as rice cultivation is concerned, there was only a marginal difference in employment by gender between aerobic and conventional rice. In the Kharif season, there is not much difference in employment between aerobic rice and conventional rice. In the Rabi season, both aerobic and conventional rice use more male labour than female labour. No general conclusion can be drawn as to whether conventional seed cultivation requires more or less labour than newer varieties.

3.4.2 Health Benefits

In general, the studies paint a picture of considerable neglect or unawareness of the need for precaution in using chemicals. However, the costs of this neglect seem to be minor both in terms of days of work lost or in terms of treatment costs. This might partly explain the neglect of safety measures.

Lalitha (2016) found that 11 farmers only responded to the question and they had incurred a total cost of Rs. 4560 and average of about Rs. 400, almost equally split between medicines, physician costs and travel costs. This compares with net income of more than Rs. 7000 per hectare for castor and Rs. 8000 per hectare for groundnut. The 20 farmers reporting loss of working days lost 111 full working days and equivalent to 31 days loss of partial days. Higher number of brinjal farmers, about 50% in Telangana suffered adverse health effects. The average expenditure incurred was Rs. 3038, which is only about 1% of the per hectare income of over Rs. 3,00,000. Patil (2016) found that a majority of the sample farmers and farm labourers (70%) were not using any protective clothes, boots and spectacles while spraying PPCs. Only 68% of the respondents wash their hands properly after PPCs spraying and 85.6% of the farmers did not receive any training regarding the proper usage of PPCs.

Manjunatha (2016) found that Bt cotton farmers suffered approximately lost three labour days and the cost of treatment of the ailment was about Rs. 1000 per episode. As far as aerobic farmers was concerned between 2 and 8% suffered from the three main diseases (stomach ache, eye and skin irritation) and on an average lost three labour days and the average expenditure of treatment was Rs. 100.

3.4.3 Environment

Information on effects of various seeds on soil quality or water quantity and quality was not elicited in the questionnaires. Usually more than 60% of the farmers disagreed with the statements that GM crops will cause humans and cattle as they carry genes from different species, or their entry into the food chain will cause health risk or that cultivation of GM crops will harm agro-biodiversity. Lalitha (2016) found that extensive groundwater extraction hastened the salinity ingress and added to the drought scenario and coincided with more farmers reporting digging of tube wells. The use of voluminous amounts of fertilizers is also a concern from a health and environment perspective as ground nut farmers were not using a rational number of sprays.

3.5 Policy Suggestions

Some of the policy suggestions emanating from the studies are as follows:

- Introduction of labelling for both domestic and export market commodities is essential for traceability
- Public private partnerships in seed development could check the monopolistic pricing of seeds and companies. PPPs should also be the preferred mode for introducing open pollinated varieties
- Involvement of farmers' representatives and Panchayat Raj Institutions in the regulatory process
- Dissemination of information to farmers in vernacular press
- Increase number of training programmes to create awareness about LMO/GMOs, cultivation practices and importance of refuge crops, proper usage of PPCs to harness the potential of GM technology
- Strong role for governance and particularly extension services as a diffusion strategy to sustain the shelf life of agri biotechnologies
- Encourage use of by-products as livestock feed
- More focus on health effects in the socio-economic assessment
- Encourage farmers to adopt protective measures as well as use protective gear and these may be provided on subsidized rates by the government along with PPCs
- Government measures to reduce the price of GM crop seeds
- GM crops offered to farmers as a package. The package may be on similar lines of SRI method
- Concurrent assessment of the implemented package for GM crop
- Promotion of interdisciplinary research and ex-ante studies on LMOs.

3.6 Conclusion

The use of GM technology in crop improvement has attracted controversy since its genesis. Regardless, GM crops have experienced an unprecedented adoption rate since its initial introduction. Particularly in India, diffusion of Bt Cotton has significantly outpaced other farm innovations. This exploratory socio-economic assessment based on trait introduction simulations in conventional crops using a CBA has also shown positive results in terms of yield. However, farmer's attitude towards GM produce have been mixed in these studies as well as other quantitative literature that has been conducted with closed questionnaires; furthermore, they fail to address the differences between small and large-scale farmers (Todua and Gogitidze 2017). The supporters of GM crops often cite the benefits GM technology has on yield as the primary reason for adoption (Qiam and Zilberman 2003). Although empirical literature advocates that higher yields are the most common motive for GM adoption, qualitative evidence verified that the potential of GM crops to raise incomes per acre of land is not the only concern of farmers as shown in this paper. In addition, Schnurr (2017) states that promoting high yields implied that increased production is the only objective that can take care of a nation's agricultural problems and by overlooking other problems such as availability of labour and access to credit markets, increased input usage among others, would likely leave farmers at a disadvantage (Schnurr 2017; Sumberg 2012; Kuruganti 2009).

Therefore, a vital initial stride is to acknowledge that GM crops are contextually very different from conventional crops and can profoundly transform social arrangements, ecological systems and material structures (Whittingham 2019). Towards this end, an interdisciplinary socio-economic assessment that includes SCBA with sensitivity analysis, scenario analysis, quantitative participatory approaches and choice-based experiments can help develop bottom-up policies. The six studies have provided a glimpse into such a cross-cutting and comprehensive socio-economic evaluation and paves the way for a robust analysis of LMOs in India's regionally diverse milieu.

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Chapter 4
Public Perceptions of Risk About LMOs: A Sociological Perspective

Ejnavarzala Haribabu

Abstract Notions of risk, benefits and expectations from technology are part of the debate on LMOs and their socio-economic assessment. This chapter provides a sociological perspective on this, taking into account the findings from the field surveys as reported in chapters in Sect. 4.2. The socio-cultural factors in risk perception are important and notions of good life are linked with this. While technology advances, perceptions of risk and benefits also change and as some technologies are perceived to be riskier than others, the public perception really matters. On the other hand, attempts to identify the public perceptions of agricultural biotechnologies have resulted in mixed outcomes as in the case of Bt Brinjal, and there is no guarantee that public perception will be uniform across countries or same for similar technologies. With new technological options like genome editing the old questions on risk and acceptability inevitably rise and studying these should be part of any exercise on SE assessment. The experience with and public perception of a non-edible GM cotton crop cannot be extrapolated to a GM food crop. Finally the technological choices and policy options have to be discussed and choices should not be limited one category of technology. Governance of technology should consider issues relating to risk, and perceived benefits from technology so that governance is not reduced to a technocratic exercise based on a narrow idea on risk, safety, and benefits.

Keywords Perception of risk · Gene editing · Risk society · Bt brinjal · Bt cotton · Process versus product regulation

4.1 Introduction

Article 26 of the Cartagena Protocol on Socio-Economic considerations states: *"the member countries may consider, consistent with their international obligations, socio-economic considerations arising from the impact of living modified organisms*

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on the conservation and sustainable use of biological diversity, especially regarding the value of biological diversity to indigenous and local communities".

In this chapter we will examine public perceptions of risk about LMOs from a sociological perspective by focusing on agriculture. This chapter draws insights from the findings of the project, supported by the Ministry of Environment and Forests (MoEF) Government of India, carried out in the five states of India, namely, Karnataka, Gujarat, the Punjab, Tamil Nadu and Telangana to explore the dimensions of risk—potential for injury, disease, loss property and life—among human beings due to exposure to LMOs and risk for biodiversity and environment.

4.2 Conceptualizing Social-Cultural Dimension of Risk

Human societies have, while interacting with nature over centuries, learnt to distinguish, between healthy and harmful foods, and accordingly acted either to accept or to ignore certain types of food derived from vegetable and animal sources. These preferences have, over a period of time, become part of cultural repertoire. This then gets transmitted to successive generations. This is how the evolution of food cultures occurs across the world. As a corollary, non-edible and unhealthy foods have been perceived to be potentially harmful to the human consumption have been avoided.

Risk is a potential harm to life of human beings (poor nutrition, illness, injury, disease, and loss of life property and environment). There are two dimensions of risk (Hillson and Hulett 2004): "*how likely the uncertainty is to occur (probability), and what the effect would be if it happened (impact). While unambiguous frameworks can be developed for impact assessment, probability assessment is often less clear*." In the modern world risk is pervasive. Before the Industrial Revolution risk was perceived in relation to natural calamities, and the threat from wild animals and diseases the causes of which were not known. With the advances in knowledge as part of the growth industrialization over the last 200 years risk has been pervading all domains of life—economic, social and cultural and health and environment. With the rapid advances in knowledge in life sciences (molecular biology and biotechnology, especially genetic engineering), nuclear science, nanotechnology (risks for human health and environment) and information technology (risk for large-scale data bases) in the twentieth century, risk perceptions about technologies have been increasing across the world today (for example, Fukushima nuclear disaster in Japan (March 11, 2011), Bhopal gas tragedy in India (December 1986) and mad cow disease in Britain in the 1980s and early 1990s). In order to understand risk, uncertainty and their management, many probabilistic models have been developed, which are based on the positivist approach to understand phenomena with a priori concepts. These models are based on observable, and quantifiable data over time and across space. They assume that measurement and quantification of description and explanation helps us in predicting the future events' accuracy. The models also project or extrapolate the dynamics of relevant parameters based on the existing explanations. These models also provide some idea of the probability (ranging from zero to one) of occurrence of a harmful event but they do not factor in the factors relating to culture and society (risk perceptions in different cultures, unknowable risks) which are not easily amenable for measurement (Hillson and Hulett 2004) Probabilistic models are not *conclusive* models. Risk research requires inputs from several disciplines including social sciences.

In the latter part of the twentieth century, especially since the 1990s, social scientists-economists, sociologists, anthropologists, psychologists and political scientists—began to examine the nature of risks that the modern societies are faced with and attempted to conceptualize risk from social science perspective. In this chapter, we shall briefly review some of the conceptual schemes that were developed by sociologists and anthropologists. Later we shall try to identify social and cultural dimension of risk from the findings of the projects carried in the five states of India.

Zinn (2004, 2009) made a comprehensive review of the sociological approaches to understand risk and uncertainty. These approaches share a common assumption that there is a significant change in modernity and uncertainty has replaced the notion of certainty and unambiguity.

Douglas and Wildavsky (1982) attempted to understand risk in cultural terms. How different cultures perceive risk and variations in conceptualization across time and space. It implies that risk is constructed in a particular context. Technologies are evaluated in terms of values of a given culture. Culture alone is inadequate to account for the perceptions of risk and uncertainty unless these perceptions are related to social social relations among different strata in the society. Kahan (2008) attempted to develop a framework of cultural cognition to empirically test the culture theory of risk proposed by Douglas and Wildavsky (1982). The cultural cognition framework attempts to: empirically investigate the "social psychological mechanisms that connect individuals" risk perceptions to their cultural worldviews…' (Kahan 2008). There are variations in the constructivist approach. Constructive realism basically subscribes to the view that nature and culture are inseparable and construction of nature in essence is based on the recognition that nature exists objectively and its construction is social interpretation (Latour 1993; Wynne 2002).

Beck (1992) made a pioneering contribution in conceptualizing risk especially in the context of modern society. Risk is not external to society, it is very much part of the modernization process. Governmentality thesis of Foucault (1991) raises the question of how power is organized to govern populations through institutions and organizations.

System theory (Japp and Kusche 2008) conceives society in terms of interrelated sub-systems and the central question is how to increase the ability of the system to evolve and how to enable the system to solve problems. A notion of trust is important in this approach. Recently trust is used to evaluate the authenticity of the sources of information regarding a new technology or a new practice. Zinn (2004) points out that there is a need to evolve a theoretical framework that combines cultural and structural dimensions of society to understand risk and uncertainty.

4.2.1 Socio-cultural and Socio-structural Factors in Risk Perception

Culture is a set of interrelated attitudes, values and system of meanings that communities attach to nature, artifacts, events, and practices. Values are expressed in terms of desirability and undesirability. Meanings are related to values and they motivate individuals to act. Attitudes are dispositions toward objects, events and practices. These dispositions range from positive to negative dispositions. For example, if a given society considers conservation of nature as desirable in its value framework, then members of the society are socialized to develop a positive attitude towards conservation and act in way that promotes conservation. However, some factors may intervene between the attitude and action. Culture also includes all the creative endeavors like production of knowledge, and artefacts, art, music, dance and sculpture, etc.

Social structure represents social relations among groups- classes, status groups, such as religious groups, caste groups, and gender. These relations are based on norms/rules, unwritten or written. The norms, in other words, are institutions that are interlinked and contribute to the maintenance of the society. Social action, according to Weber (1964, p. 88), is action of individuals who attach subjective meaning to the action and the subjective meaning takes into account the behavior of others and thereby oriented in its course. Social action occurs in the institutional space. Institutions enable individuals to perform certain actions and constrain them from performing certain other types of action (Giddens 1993). The norms/rules are based on socially accepted values and meanings or based on power relations. Meanings, as mentioned above, are culturally mediated that motivates individuals to act in such a way that is culturally relevant and appropriate. Culture influences social action and social action may change culture. Technological innovations attempt to change social relations at work place and in the family; and our values and meanings. For example, information and communication technologies have changed social relations at work place and people's attitude towards interpersonal communication. Social relations and culture change over time. In other words, human actions are influenced by interests arising out of belonging to a particular social group or a community or exercising control over resources and a system of meanings and values that the group holds or shares with other groups (Haribabu 2004). Barnes (1983) argues that goals and interests influence the production of knowledge. We may extend these concepts—culture (values and meanings) and institutions or norms (interests)—to understand perceptions of risk and uncertainty.

4.2.2 Interests and Meanings

Interests include economic, professional and business and political interests. Meanings in combination with values are attached to human life and health, food, clean air, water and soil, biocultural resources such as seed, biodiversity, accumulated knowledge and aesthetic values. For example, a company that produces genetically modified seed would like to sell the seed to as many farmers as possible to further its business interests.

Farmers, as a community would be interested in using seed that is resistant against biotic stresses like diseases and abiotic stresses like drought and salinity and promises good yield. They also would be interested in ensuring that accessibility and affordability of the seed. Historically farming communities, selected the seed, bred it and conserved the seed in situ. Seed, in other words has become a biocultural resource. Further, they would be interested in ensuring that the food grains conform to their aesthetic values of color, size of the grain and cooking quality. For example, hybrid rice, although yielded more compared to traditional varieties the hybrid rice was not acceptable to consumers as it was sticky and the cooking quality was not good in areas which are traditionally rice growing areas (Janaiah 2002, 2003). Hence, the extent of adoption in South hybrid rice is very low (5%).

Janaiah (2002) observes: "*… in spite of huge capital and human resources invested over the past decade to develop and supply hybrid rice technology for Indian farmers, there has not been a noticeable impact on the sector. India has tried to emulate China's success story in the area of hybrid rice research and development, but Indian farmers have not readily accepted hybrid rice technology.*"

Regulatory norms were evolved to protect interests and values of communities. In traditional societies regulatory norms regarding access to community resources such as forest resources in terms of quantity, and seasons in which the resources can be accessed, etc., were enforced by taking recourse religious norms (Haribabu 2010). In the case of modern societies regulatory framework is based on codified law that can be enforced through courts of law. Regulatory framework is based on a set of values and these are operationalized in the form or norms/standards that can be implemented. Today we speak in terms of broad-based governance, involving all the stake holders, rather than regulation. A question raised most often in the context of regulation is: who is going to regulate the regulator? It is in this context the concept of Post- Normal science assumes importance. Funtowicz and Ravetz (1993) observe that the earlier conceptual schemes that attempted to understand the dynamic interaction between science and technology, on the one hand, and society, on the other, are no longer adequate. They argue that, in today's context, when "*facts are uncertain, values in conflict, and stakes high and decision is urgent*", we need a new approach that accommodates these dimensions in policy-making process and policy choice. Relations among science and technology on the one hand and science technology and society on the other are changing rapidly. Post-Normal science examines the changing relations between science of facts and values of governance.

4.2.3 Risk Studies in India

In India risk studies have been initiated since the later part of the twentieth century in the context of environmental pollution—of air, water and soil—due to untreated industrial effluents that entered environment and contributed to the pollution of life supporting systems. Air pollution has become a serious issue causing several health problems for the population, especially in urban areas culminated in a series of policy measures to address risks arising out of air, water and land (soil) pollution. The Air (Prevention and Control) of Pollution Act was announced in 1981 to regulate air pollution. Similarly, the National Environment Policy 2006, was announced by the Government of India with the objectives of: (a) conservation of critical environmental resources; (b) intra generational and intergenerational equity to ensure livelihood security for the poor; (c) efficiency in environmental resource use; (d) environmental governance that is transparent and rational; and (e) enhancement of resources for environmental conservation. The policy recognized the need to address degradation of agricultural and forests, land (soil) pollution, biodiversity and conservation of environmental resources. Availability and access to adequate quantity of water for various purposes including agriculture and quality of drinking water are important issues in India. To address these issues of pollution of surface water and underground water, the first National Water Policy was announced in September, 1987 which was later revised in 2002 and 2012. The Government of India has been responding to the empirical problems associated with pollution of land, water and air through its policy interventions.

There is a need to understand in the context of the Article 26 of the Cartagena Protocol on Socio-Economic considerations regarding LMOs, as to what are the perceptions of risk and uncertainty prevalent across several stake holders- farmers, scientists, seed industry and seed dealers, consumers, government and regulators in the context and to what extent their perceptions are related to their interests, values and meanings.

As LMOs, for example, a genetically modified seed, tends to change the meanings that members of the farming communities and consumers of agricultural products have been sharing. Different stake holders—farmers, consumers, government, regulators, and public at large tend to develop an attitude towards LMOs and evaluate it from the point of view of their interests and meanings and as a corollary perceive risk. Before we discuss findings related to risk it is important to look at the evolution of agricultural policies from the 1950s.

4.3 Evolution of Agricultural Policy in India

As part of the strategy to increase the output of food grains the Green Revolution package (consisting of mechanization, irrigation, High Yielding Varieties, institutional credit, chemical fertilizers and pesticides) was introduced first in irrigated regions of the Punjab and Haryana in the early 1960s. It helped in increasing the yield of wheat, to start with. Wheat production increased from 11 million tons in 1966–67 to 88.94 million tons in 2014–15 (Department of Agriculture and Cooperation & statistics, Government of India 2014). Later the technology was extended to rice crop. The total production of rice was around 20 million tons in 1950 which increased to around 106 million tons in 2013–14. However, the impact of the green revolution package has been uneven. Rao (1994, p. 65) noted: "gains from the green revolution so far has been limited largely to wheat and rice grown more or less in homogeneous tracts- both agro-climatically and socio-economically- served with assured sources of irrigation and inhabited by resourceful farmers." The green revolution practices led to several unintended consequences: overuse of fertilizers and pesticides and loss of soil health, pesticide residues in the soil and food. Shiva (1991) argued: "*The Green Revolution has been a failure. It has led to reduced genetic diversity, increased vulnerability to pests, soil erosion, water shortages, reduced soil fertility, micronutrient deficiencies, soil contamination, reduced availability of nutritious food crops for the local population, the displacement of vast numbers of small farmers from their land, rural impoverishment and increased tensions and conflicts. The beneficiaries have been the agrochemical industry, large petrochemical companies, manufacturers of agricultural machinery, dam builders and large landowners*." The green revolution also affected the health of the people as several studies have shown pesticides of various kinds in the blood samples of farmers (Mathur et al. 2005; CSE 2007). The increasing trend to shift to organic agriculture is a reaction to the synthetic chemicals based green revolution technology and the unintended consequences of the green revolution.

The FAO report (2017 p. xi) also pointed out the following consequences of high-input, resource-intensive farming systems: (a) massive deforestation; (b) water scarcities; (c) soil depletion; (d) and high levels of greenhouse gas emissions. The report observed that agriculture which has led to the above conditions "cannot deliver sustainable food and agricultural production." MacIntyre et al. (2009) also draw our attention to the effects of resource-intensive agriculture and suggest the need for alternate ways of organising agriculture. Swaminathan (1987) argues that research efforts must be directed towards development of technologies that are not only scale-neutral but also resource-neutral.

In this context, the Government of India's New Agricultural Policy (NAP) of 2000 emphasized the need to promote "*technically sound, economically viable, environmentally non-degrading, and socially acceptable use of country's three natural resources—land, water and genetic endowment to promote sustainable development of agriculture, increasing cropping intensity through multiple-cropping and inter-cropping*". That productivity based on the green revolution technology has reached a plateau was recognized by the New Agricultural Policy of 2000. The NAP aimed to attain, among other things, over 4% annual growth rate by the 2020. The NAP also mentions the importance of continuous interaction between farmers on the one hand and technology producers on the other, through a more effective extension system. However, nearly one and a half decades after the announcement of the NAP farmers are not able to reach a break-even point in their investment in agriculture, let alone making profits. Speaking at an agriculture conference organized by Indian Council of Food and Agriculture (ICFA 2002), Dr. M. S. Swaminathan said: "Indian agriculture is facing challenges of climate change. Income of farmers is not going up. There is a continuous demand for loan waivers," he said.

4.3.1 Genomics and Agricultural Policy

The NAP- 2000 aimed at the use of biotechnologies to address the problems of abiotic stresses like drought and salinity, etc. and biotic stresses like fungal, bacterial and viral diseases and to enhance yield in crop plants. It is in this context, solutions based on genomics, especially genetic engineering solutions are sought to be explored. However, the genetic engineering technology has become controversial because of the nature of technology which involves transfer of genes across species and the proprietary control over the technology (Mallick et al. 2011; Haribabu 2012). Genetic engineering was approved to improve cotton crop in 2002, though the farmers in Gujarat were already using the transgenic cotton seed without prior approval of the regulatory bodies. This is another major shift in agriculture which demands that the farmers acquire knowledge of modern genetics and associated practices. Knowledge regarding risk associated with genetically modified seed regarding is still limited. What would the GM seed do to human beings, non-human life forms? Whether or not GM food is fit for human consumption from the point of view of moral, ethical and religious considerations are pertinent questions. The regulatory system has not been able to carry out independent studies or recommended for commissioning independent studies. Studies on risk and uncertainty assumed more prominence in public discourse with the introduction of genetically modified cotton seed and later with the attempts to introduce genetically modified brinjal, which is a food crop. On the basis of the recommendations of the Genetic Engineering Approval Committee (later changed to Genetic Engineering Appraisal Committee) under the ministry of Environment and Forests (MoEF) attempts to commercially release Bt Brinjal were opposed by farmers and civil society organizations by drawing attention to risks associated with genetic engineering technology, especially its effect on human health and health of non-human life forms and environment in general. In this context, Mr. Jayaram Ramesh, the then minister of Environment and Forests (MoEF) conducted public hearings in six cities and sought the opinions of several scientists in India and abroad (CEE 2010). On the basis of the proceedings of the public consultations and expert opinion, the ministry imposed moratorium in (The Ministry of Environment and Forests Goverment of India 2010) on commercial introduction of Bt Brinjal in the country and suggested that further independent studies have to be carried out before a final policy decision is made. The imposition of moratorium on Bt Brinjal was a key learning exercise in understanding the risks and uncertainties associated with genetically modified Brinjal by the stake holders. Kalle and Haribabu (2016) traced the journey of Bt Brinjal from the initial attempts to release it commercially on the basis of the GEAC recommendations in October

2009 to the decision on imposition of moratorium in 2010. The moratorium decision on Bt Brinjal may be seen as an attempt to establish a democratic governance of technology framework.

The Parliament of India was also concerned about the genetic engineering technology and the Fifteenth Lok Sabha appointed a Committee on Agriculture (2011–2012) to look into the issues of risks and uncertainties associated with the genetically modified crops. The committee submitted its report in 2012. The Committee held public consultations, reviewed the regulatory systems in other countries, the recommendations of the GEAC and the biosafety assessment reports submitted by the company that produced the Bt seed. The Parliamentary Committee observed:

> Having gone through the voluminous evidence gathered by them the Committee can safely conclude that all is not well with the regulatory mechanism put in place by the Government for oversight of cutting-edge technology as sensitive as GMOs and products thereof (2012, p. 80).

The committee further noted after going through the regulatory systems of various countries observed that India does not have health infrastructure to deal with the adverse effects of genetically modified crops in India. The Committee recommended:

> In such a situation what the Country needs is not a biotechnology regulatory legislation but an all encompassing umbrella legislation on biosafety which is focused on ensuring the biosafety, biodiversity, human and livestock health, environmental protection and which specifically describes the extent to which biotechnology, including modern biotechnology, fits in the scheme of things without compromising with the safety of any of the elements mentioned above (p. 107).

The debate on genetic modification of food has entered the portals of the Indian Legislature. Even before the controversies over genetic engineering are yet to be resolved and the potential of genomics-based non-transgenic approaches such as the Marker-Assisted Selection (MAS) for crop improvement are being explored advances in genomics have led to gene editing technology, the latest genomics-based innovation.

4.3.2 Gene Editing

Genetic modification involves modification of the genome of an organism by introducing gene(s) from another organism belonging to a different species by using gene transfer tools, for example, the gene gun. The latest gene editing technology involves repairing or replacing a stretch of DNA by using Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR). CaS9, an enzyme, is used as a molecular scissors to cut the gene or a stretch of DNA that is considered potentially harmful. CRISPR—CaS9 is the gene editing tool (Welcome Trust, October 5, 2016). The technology was invented by Jennifer Doudna Charpentier and their colleagues in (2014). The technology has become controversial because removing a stretch of DNA may affect the integrity of the genome and may cause unintended consequences as the edited gene may be involved in controlling a trait singly or in combination with other genes. Risks and benefits of the gene editing technology for agriculture, human beings (gene edited human embryos) and biodiversity have to be fully worked out. Moreover, Jennifer Doudna (2015) one of the co-inventors of the technology recently said (TED talk, September 29, 2015) that there is a need for global discussion on the risks and benefits of the technology as it is already surrounded by controversies -scientific, ethical, social and control over technology through IPRs. She advocated for a global "pause" on the application of the technology until the controversies are resolved. There is a need for a global framework of governance of the gene editing technology. In other words, the gene editing technology is no exception to technologies that have inherent risks. Gene editing is next generation technology when compared to genetic modification but issues on risk, perception of risk, Socio_Economic (SE) assessment are equally applicable here. Genome editing has implications for agriculture and whether genome edited crops should be considered as GMOs or not is an issue that has to be addressed.

Hansson (2018) points out that the role of values in science has been particularly controversial in issues of risk. He further states that there is also a discussion on the need to strengthen the impact of certain values in risk assessment, such as considerations of justice human rights, and the rights and welfare of future people. Hansson (2018) also observes: "*Issues of risk have also given rise to heated debates on what levels of scientific evidence are needed for policy decisions. The proof standards of science are apt to cause difficulties whenever science is applied to practical problems that require standards of proof or evidence other than those of science*".

In other words, discussion on the risks and uncertainties associated with technologies are related to the notion of good life. Irrespective of technology and advancements in technology, perceptions will matter and particularly the perceptions of farmers matter more as ultimately they are the end-users of any agricultural technology. But public perception that includes perceptions of other stakeholders is obviously important as that contributes to acceptance or rejection of the technology and the outcomes (in this case the outputs from crops, their derivatives and end products). Studies done for this project provide an interesting picture and we will discuss them in the next section.

4.4 Farmers' Knowledge and Willingness to Pay for New Seed: An Overview

Over 90% of the farmers in Tamil Nadu included in the study were aware about GM crops, as they have been cultivating Bt Cotton. Farmers felt that that before introducing genetically modified crops, farmers must be given all the relevant information regarding the seed and crop management, so that they can take all precautions that are needed to raise a genetically modified crop. Some of them had reported that they burnt their fingers in Bt Cotton when it was introduced as they did not have the full knowledge about Bt cotton cultivation.

Though most of the farmers in Gujarat (91%) were more familiar with Bt cotton and in the north-eastern Karnataka, among the different stakeholders, 100% of all the academicians/researchers had knowledge about GMO crops followed by input dealers/traders (70%) and farmers (42%) and very a smaller number of farm laborers had knowledge about the GMO crops. The majority of the academicians/researchers, seed dealers, farmers and farm workers, believed that GM cotton gives higher yield compared to other hybrids. In the Raichur region, Karnataka state, about 96.67% of farmers, 64% of farm laborers, cent percent of input dealers/traders and 75% of the academicians/researchers responded that GM cotton needs higher inputs than that of other cotton hybrids.

The farmers' perception about LMOs is that about 92.67% of the farmers have shown tendency towards acceptance of new variety of LMOs with desired traits. Only 7.33% of the respondents negatively responded in acceptance of new variety of LMOs. The responses were based on the experience with Bt cotton cultivation. Bt technology is a crop protection technology and not a yield-enhancing technology. The experience with a non-edible GM cotton crop cannot be extrapolated to a GM food crop.

Farmers in all the states were willing to pay more to a new seed, including the GM seed ranging from 10 to 50% of what they were paying for the hybrids or inbred lines at the time of the study. They expected that the higher price for the GM seed would give higher yields and they wanted a guarantee that the seed would perform according to the promises made by the seed companies at the time of buying the seed. It is clear that the seed companies must give comprehensive and reliable information about the seed and practices associated with its cultivation at the time of selling the seed to farmers.

4.4.1 Perception of Risk and Uncertainty Among Farmers

Pidgeon (1998) argues: "the findings from risk perception research do hold implications for the ways in which risk analysis and regulation should be done". It means that the perceptions of the farmers, as one of the primary stake holders, have to be taken into account in policy formulation regarding governance of technology so that a more inclusive and sustainable policy may be formulated. In the research that was carried out in different parts of India we shall see how and in what ways farmers perceive risk and act to minimize risk with their knowledge.

In Tamil Nadu farmers in general did not have any idea about possible adverse effects of GM crops on human, on livestock or on environment. In the Punjab, the farmers based on their experience with Bt cotton, felt that the genetically modified food crops may increase productivity. They perceived risk regarding the biocultural resource—base like germplasm. They were apprehensive of risk to the diversity in germplasm as the genetically modified seed may minimize or eliminate diversity.

Farmers in the Punjab perceived risk of losing cultural resources like knowledge, social networks and stability of agriculture as an occupation, and for them cultivation of a GM food crop is like entering "*untested waters*." It means that they perceive uncertainty, one of the dimensions of risk, in cultivating GM food crop. The farmers are reflective on more than one dimension of their option of cultivating GM food crop.

In Karnataka the study found that there were differences in the perceptions of different stake holder groups based on their interests. While the scientists and academicians mentioned that the GM crop may increase productivity whereas farmers, farm laborers, input dealers/traders perceived uncertainties regarding the increase in yields. They were ready to pay more for the seed if a guarantee, regarding higher yield is given. However, scientists and academicians did perceive a risk arising out or gene flow from genetically modified crops to non- GM crops which would lead to contamination of the non-GM crop. They seem to recognize a threat to diversity in a crop. In other words, they perceive risk to the primary gene pool of a crop as a result of the introduction of genetically modified seed due to gene flow and the attempts of the seed companies to sell their own seed will eventually eliminate diversity, as perceived by the farmers in the Punjab. All the academicians and scientists did perceive that production and sale of genetically modified seed would increase monopoly over the seed as the GM seeds are proprietary products of big corporations which tend to restrict access and affordability.

4.4.2 Governance of Technology

The perceptions of the farmers in all the five states regarding risk and uncertainty; and their expectations regarding the performance of the GM seed are related to governance of technology.

Two important dimensions of risk analysis are: judgements on the acceptable level of risk and time element. Judgements on "acceptable levels" of risk are never purely scientific when the weighing of incommensurable costs and benefits involves trade-offs among diverse values (Barbour 1980 p. 175). The time element refers to the timeframe over which a given technology is effective and safe. For example, how long Bt toxin will provide resistance against Bollworm? Regulatory arrangement must deal with these issues based on values of: (1) equity; (2) justice; and (3) cultural compatibility in terms of values and meanings that are attached to notions of culturally relevant preferences as mentioned above. Equity essentially means equitable access to technology and affordability. The operational part of this statement is as follows: As the paying capacity of the farmers varies across different sections of farmers, there is a need to make sure that those farmers including small and marginal farmers, many of whom are tenant farmers, can afford to buy the seed. Justice implies the notion of fairness in the interaction among the stake holders on the one hand and stake holders and the environment on the other. For example, whether or not the price of the GM seed is fair? The issue of the cost of the seed was raised by farmers in all most all the states. To recall, the combined state of Andhra Pradesh in the year 2006, had to invoke the provisions of the Monopolies and Restrictive Trade Practices Act of the Government of India 1969, to make the company that produced the Bt cotton seed to reduce the price of the seed (Haribabu 2014).

Farmers in Telangana state included in the project believed the government should be strictly regulating any commercial introduction of new varieties (GMOs, LMOs) and put in place proper environmental safety precautions. This issue must be incorporated into the governance framework.

Another issue pertinent question regarding governance of GM technology is the issue of the insect pest developing resistance against the toxin, for example, Bt toxin over a period. As the host and pest are co-evolving organisms, the pest develops resistance against the toxin by adapting itself to the toxin or by mutation. For example, in the case of Bt cotton, the first generation Bt cotton seed has been shown by the company to be ineffective in fighting the Bollworm and the company introduced the second generation Bt cotton seed on the basis of its own assessment (Haribabu 2014). The governance framework must create the awareness among the farmers about the nature of technology and prepare them for such an eventuality.

Frameworks that seek to regulate the genetic modification of seed vary across countries. India and the European Union adopted process-based regulations in line with the *Codex* guidelines. In contrast, the USA has used the notion of "substantial equivalence" to indicate that the food produced by genetic engineering technology and other conventional methods is substantially equivalent. According to Jasonoff (2003: 158), an increasing emphasis on "risk assessment", "sound science", "evidence-based decision- making" in the official discourse is indicative of the "retreat from precautionary approaches to regulation. Participative policy process emphasizing the *precautionary principle* brings to light the contrast with the broader trend towards a *technocratic model* of governance in the United States (Jasonoff 2003: 158). India is a signatory to the Cartagena Protocol on Biosafety, which emphasizes the use of the precautionary principle.

4.4.3 Towards Democratization of Science

Recently scholars have begun to explore agriculture from Science, Technology Studies (STS) perspective which looks at the interface between knowledge, public policy, and society, culture and environment. Technology is not merely a disembodied gadget. It is a socio-technical system (Hughes 1985). To understand different interrelated dimensions of agricultural technology, it should be seen as a socio-technical system with the following interacting sub-systems: (a) knowledge: genetics, soil science, irrigation; (b) technology and techniques of intervention; (c) social organization to implement technology: R&D organizations; (d) end-users—farmers and the knowledge they accumulated over the years; (e) government; (f) seed industry, fertilizer and pesticide industry; (g) nature; and (h) consumers. National System of Innovation perspective views innovation as an outcome of the interaction among the participating organizations and communities. Learning is the key element in the interaction (Lundvall 2007; Lundvall et al. 2009). Learning helps in looking at the problem from other's point of view to arrive at a shared paradigm of understanding and intervention. In other words, innovation is generally seen as an outcome of the interaction among constituent elements that learn from each other and bring about new products and processes. As part of the learning process perceptions about risks and uncertainties must be debated by the stake holders and capacities must be built to deal with them. The NIS must appreciate the risk perceptions of farmers, who overtime developed culturally appropriate strategies, for example, minimizing risk in terms of cultivating multiple crops simultaneously.

There is a need to understand risk-minimization strategies of farmers in dry land areas. For example, in dry land areas farmers cultivate multiple crops that ensure their food security. Farmers in dry land areas have accumulated knowledge regarding the crops that are drought resistant and arrived at a combination of crops provide them food security (Jodha 2007). In the dry land areas of Southern India, it is an age-old practice that farmers cultivate multiple crops to ensure food security. In dry land areas of Rayala seema districts of Andhra Pradesh (Chittoor, Kadapa, Anantapur, Kurnool and dry land areas of Nellore district) farmers have been cultivating multiple crops-groundnut or peanut, Bengal gram, Urad Dahl, moong Dahl, horse gram, soy bean, in small quantities and the produce they got from all these crops, even if in relatively small quantities ensured food security over the year after the harvest. Keeping cattle—cows and buffaloes—combined with the output from the dry land crops ensures food security even in adverse conditions. This should be recognized as one of the adaptation mechanisms against climate change.

Technological innovations alone are not adequate unless there are innovations in institutions and organizations. In the present context, interlocking innovations—technological and institutional—in the following areas are needed: (a) development of seeds of crops that are resistant against biotic and abiotic stresses; (b) water saving techniques; (c) a gradual shift from synthetic chemical-based agriculture to towards organic agriculture and multiple crops; (d) open source innovations to improve access to knowledge. Institutional innovations in the form of new context-specific policies and related R&D organizations that are ready to learn from the stake holders and shape the research mandate to solve strategic problems are imperative.

To summarize, risk is pervasive in the contemporary modern world as risk is "manufactured" in contrast to risk in non-modern societies which tend to be "natural" (Luhmann 1993). As mentioned above, manufactured risk is related to: (a) physical—seed, environment and non-human life forms; (b) organizational; (c) socio-economic; and (d) cultural domains in the present-day world. In the case of agriculture there are risks associated with nature, biotic stresses like diseases and abiotic stresses like drought and salinity. We have seen that the farmers perceive risks with respect to genetically modified food crops based on their experience with Bt cotton cultivation. Farmers' economic interest lies in pursuing higher returns on their investment and for that they are willing to pay more for a technology that ensures better returns on their investment. At the same time, they perceive the uncertainty regarding crop protection and higher yields and threats to cultural aspects like the accumulated knowledge, biocultural resources like conserved diversity in a crop, aesthetic values like the color, size and taste of the food grains associated with genetically modified food grains, and potential harm for health of the people and the environment that includes cattle, and useful insects and birds. As mentioned above, to deal with the complex and cross-cutting issues involving interrelated domains we need to evolve a broad-based and democratic governance framework. The decision-making process that involved stake holders across the country led to the moratorium on Bt Brinjal. Involving stake holders in the decision-making process is an instance of democratization of science.

4.5 Conclusion

To conclude, we have seen that in the five states, the perceptions of the stake holders in general and farmers in particular regarding risk and uncertainty relate to their interests cultural values. The farmers do want to increase productivity but they also are concerned with the potential harm that the genetically modified seed would to human health, environment, biodiversity, traditional knowledge and traditional social networks that played an important role in sharing knowledge and exchanging resources. Their concerns emerge from their economic, social, cultural and aesthetic considerations. It implies that there are cross-cutting issues that involve several interrelated domains as our brief literature review suggested. The stake holders demonstrated their reflexivity in looking at the technological innovations. The Indian Government at the center and the state/regional governments must recognize the significance of the National System of Innovation (NIS) in general and agricultural innovation system in particular. The NIS must closely interact with farmers and learn from the farmers in different agroclimatic zones as to what kind crops and traits in a given crop need improvement. We should explore the potential of genomics-based Marker-assisted Selection (MAS) Technology as a stand-alone technology for crop improvement. Innovations may be produced in open source mode using the MAS technology to provide solutions to biotic and abiotic stresses and yield enhancement. The MAS technology is based on exploring variability with the primary gene pool of a crop and hence is non-controversial. There is also a need to evolve a framework of governance of technology based on values of equity and justice. In other words, the governance must be broad-based, more inclusive and democratic. The emerging new technologies like gene editing also must address ethical aspects which refer to individual's autonomy, privacy, and dignity, as enunciated by the UN in its resolution on Bioethics (2009) and socio-economic issues like inclusivity, equity, and justice.

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Part II
Case Studies

Chapter 5
Socio-economic Assessment of LMOs: Insights from Punjab and Haryana

Rabindra Nath Padaria

Abstract The study was carried out in the states of Haryana and Punjab. These states have witnessed the adoption of Green Revolution technologies and also have undertaken Bt cotton cultivation. Based upon the random sampling technique, Mansa and Bhatinda districts from Punjab, while Sirsa, Hissar and Fatehabad districts from Haryana were selected among the predominantly cotton growing districts. A sample of 220 farmer respondents was selected for testing the questionnaire through multistage sampling. The trait selected for the study was aphid resistance in mustard, considering the importance of aphid management. Similarly, due to menace of weed in wheat, herbicide tolerance in wheat was selected as another trait. The yield potential and efficacy in management of pests (with the highest mean score of 9.67), were considered as the first and foremost criteria for selection of any Bt. hybrid followed by the germination potential; cost of seed; plant type; input requirement; suitability to farm; safety to human and cattle; irrigation intensiveness; and crop duration. There was a drastic fall (of about 32%) in the number of pesticide spray and cost on spray also reduced significantly, with adoption of Bt cotton. While the benefit–cost ratio increased by about 22%, the yield increased by nearly 36%. Adoption decision among farmers was influenced by variables such as the number of family members engaged in farming, social participation and social network. Factor analysis revealed that the major domains of risks were related to seed systems, resource systems, openness in innovation generation and regulations systems. In both the states studied, it was found that majority of farmers lacked understanding or knowledge about genetic modification of the crop; though all of them had cultivated Bt Cotton and perceived that it had led to yield enhancement and increase in income.

Keywords Risk perception · Genetic modification · Gene flow · Bt. cotton · Factor analysis

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5.1 Introduction

Advancement in recombinant DNA (rDNA) technology has shown immense potential in overcoming production constraints that are more difficult or intractable with conventional breeding. With the recombinant DNA Technology, the genetic information of living organisms can be modified in a novel ways, by enabling inter-species, inter-genus or even inter-kingdoms transfer of one or more DNA fragments. Organism thus developed are called transgenic organism (plant or animal) containing a gene or genes which have been introduced artificially into their genetic makeup.

In recent years, the practical utility of alien genes through transgenesis has been extensively demonstrated and transgenic plants harbouring genes for insect pests' resistance, herbicide tolerance and increased post harvest shelf life have been developed. Genetically Modified (GM) crops and foods have emerged as promising alternatives for enhancing the food and nutritional security, though with mounting debate on risk and concerns related to health and environment. However, despite its potential benefits, there is reluctance towards its application for socio-economic betterment and the public acceptance has been with mixed response and ambivalent attitude. Notwithstanding the unprecedented rate of diffusion and adoption with sustained increase in acreage, enhanced yield and return and growing acceptance of Bt cotton; worldwide debate upon the use of transgenic crop remains alive. Criticisms primarily faced by the transgenic technology include the bio-safety concerns, which include transgene movement to other varieties and wild relatives leading to possible development of super weeds, erosion of genetic diversity and ecological disturbance; wide-spread apprehension about toxicity or allergencity induced by transgenic products to humans and animals; its adverse impact on non-target organism; emergence of more virulent forms of pests and pathogens; etc. Besides biosafety concerns; IPR and ethical issues form the basis of debate towards adoption of transgenic crops.

Genetic engineering and its application in agriculture especially in the context of India, where majority of population depends on agriculture as a mainstay for livelihood, involve too many questions. GM foods have the potential to solve many of the world's hunger and malnutrition problems, and to help protect and preserve the environment by increasing yield and reducing reliance upon chemical pesticides (Swaminathan 2009). As the Food and Agriculture Organization in 2004 has rightly pointed out, "*science cannot declare any technology completely risk free, genetically engineered crops can reduce some environmental risks associated with conventional agriculture, but will also introduce new challenges that must be addressed. Society will have to decide when and where genetic engineering is safe enough*". Arguments, both for and against the cultivation and use of the Genetically Modified (GM) crops, are varied and there is a wide consensus that assessment should take place on a case-by-case basis before genetically modified food is brought to the market.

As there is a greater apprehension towards socio-economic issues, the Paragraph 1 of Article 26 of the Cartagena Protocol on Biosafety provides that Parties may take socio-economic considerations into account in decision-making on living modified organisms. Globally, initiatives are afoot towards policy formulations for taking socio-economic considerations into account in decision-making on living modified organisms while being consistent with relevant international obligations, which include trade agreements, environmental agreements and human rights agreements. However, there is a wide gap in framework for delineation of socio-economic considerations and methodological paradigm to analyze and quantify the related issues. Lack of clarity on what socio-economic issues may be considered in the context of Article 26; lack of guidelines on socio-economic assessments; and lack of methods and tools for socio-economic assessments often cripple the policy development initiatives.

Considering the predominance of wheat in food basket of the country and its large scale cultivation in Indo-Gangetic Plains; it was selected for study. Wheat is grown in India in an area of about 30 Million ha with a production of about 99 Million tonnes. The normal National productivity is about 2.98 tonnes/ha. Haryana and Punjab together account for about 21% of all India wheat acreage and nearly 32% of production. Besides pests, weeds are serious menace in wheat cultivation.

The average yield loss caused by weeds in different wheat growing zone ranges from 20 to 32%. It is reported that about 20–40% yield loss is there in wheat due to weeds in India. In extreme cases the losses caused by weeds can be up to complete crop failure (Malik and Singh 1995). The cases of complete crop failure were quite common during late seventies in the absence of effective herbicide and mid nineties due to heavy population of *Phalaris minor* after the evolution of resistance against isoproturon. Under both the situations, some of the farmers were forced to harvest their immature wheat crops as fodder (Chhokar and Malik 2002). Wild oat is another grass weed, which is highly competitive.

Since herbicide tolerant transgenic wheat has been on verge of deployment, the herbicide tolerance trait in wheat was selected for the study.

Along with wheat, mustard is another important crop in Indo-Gangetic plain. Also accelerated production of oilseed is an important mission of the country to meet out the needs of the people. In India, under the name rapeseed and mustard three cruciferous members of Brassica species are cultivated (Bhatia et al. 2011). *B. juncea* (Indian mustard or commonly called rai) is the chief oil yielding crop while three ecotypes of *B. campestris* ssp. oleifera, viz. brown sarson, yellow sarson, toria and *B. napusare* are grown to a limited extent. Among the biotic stresses, damage caused by aphids is a major constraint in the growth and productivity of these crops. Its unusual reproductive habits and atypical feeding mechanism make aphids one of the most economically important groups of pest in agriculture. Losses in yield of oilseed Brassica due to attack by *L. erysimi* have been reported several times and the mean loss in yield has been estimated to vary from 35.4 to 91.3% (Singh and Sachan 1994) under different agro-climatic conditions and is about 54.2% on all India basis (Bakhetia and Sekhon 1989). Given this, aphid management in mustard is very important and considering this scenario, aphid resistance was selected as a trait for the study.

The objectives of the study was to identify the socio-economic, cultural and ecological concerns related to LMOs and to devise and validate survey instrument for analyzing these concerns related to LMOs.

5.2 Methodology

Socio-economic assessment of living modified organisms encompasses multidimensional spheres covering the social and behavioural contexts; community welfare and culture; livelihood systems; economic gains; market and trade; ecological changes; control, regulation and arbitration systems; innovation development processes and institutional arrangements, etc. Therefore, the framework for assessment would need characterization of audience or clientele and specification of parameters to ascertain the likely effect of the living modified organisms. For the present study, the stakeholders related to development, deployment, adoption and consumption of living modified organisms particularly the major crops like cotton, wheat and rapeseed mustard were specified.

For identifying the traits for which living modified organisms (in this case transgenic crops) and parameters for assessment of their likely impact, stakeholders' workshop and Focus Group Discussion methods were designed and applied.

The study was conducted in Punjab and Haryana with purposive selection on account of their rich experience of application of innovations (firstly of Green Revolution technologies in mid-1960 s and later Bt. Cotton hybrids from 2006) and witnessing both desired as well as undesired socio-economic consequences. With multistage random sampling the locale and respondents were identified. Since Bt cotton is the only living modified or transgenic crop being deployed in India; it was used as the referent crop in this study and accordingly the primary respondents, the farmers, were restricted to those having experience in cultivation of Bt cotton. At first stage, among the districts having predominant cultivation of cotton in Punjab, Bhatinda and Mansa districts were selected randomly; while Sirsa, Hissar and Fatehabad districts were selected from Haryana. From each district two blocks and from each block two villages were selected randomly. The total sample size comprised of 220 farmers. The primary data were collected through personal interviews with the farmers, while questionnaires were mailed to the scientists and scholars.

What constitutes socio-economic considerations and how they would be measured were the major tasks under this study. Based upon reviews of literature and focus group discussions (Kitzinger and Barbour 1999) with various categories of people representing scientific community, farmers, social activists and social groups, media groups, traders, seed companies and extension professionals a narrative was prepared. The criteria and indicators of likely impact were finalized. Besides, cardinal indicators with respect to relative advantage and economic gains, issues emerging in context of behavioural, social (including health) and cultural dimensions needed attention with qualitative perspective. Therefore, both qualitative and quantitative indicators and methods were used.

5.3 Results and Discussion

Innovations have been instrumental in driving the growth of any society. However, innovations are like double- edge swords as there may be desirable as well as undesirable consequences or intended and unintended consequences. Literature is replete with people's resistance to several innovations on account of perceived undesirable consequences. Introduction of any innovations in a social system is therefore, a very delicate as well as cumbersome process. Rogers (1995) tried to identify the characteristics of innovations viz, relative advantage over the existing practice or method; compatibility with existing values, experience or endowments; complexity, trialability and observability; which often become criteria for adoption by an individual or a social system or any organization. The innovation should be able to give some additional gain or save the loss or reduce the drudgery in comparison to the existing methods. The innovations should be compatible to social system and resource endowments and it should be easy to use. At the same time, it should be possible to be tried out at smaller scale and further, the results or performance of the innovation should be discernable. The wide scale application of Green Revolution technologies and the unprecedented speedy rate of diffusion of Bt cotton in India were possible because the innovations' attributes as mentioned above fit well with the user groups. However, the resistance and opposition to these innovations are still alive despite large scale acceptance. The discontentment lies in the undesired consequences as well as perceived risks. People's resistance across the world about development paradigm has gained the attention due to perceived risks to ecology. People's resistance to application of biotechnology led innovations is due to perceived risks to health, ecology and economy and many times due to cultural and control systems (monopoly, patent rights, etc). Under such scenario when the world is grappling with the emerging problems of food, nutrition and livelihood security to millions of people; resistance to biotechnology-led innovations; which hold immense potential to eradicate most of these problems; policy makers need clarification on understanding the nature and basis of resistance.

Socio-economic considerations have assumed greater significance in this milieu as most of the reasons of resistance or rejection of living modified organisms has roots in social, cultural, economic and ecological context. Therefore, it becomes essential to understand the prevailing concepts and logics among the stakeholders. However, the larger question is what are the appropriate means and methods to gain these understanding. For this study, stakeholders' workshop and focus group discussions were conducted. Later, matrix ranking was used to have a quantitative assessment.

5.3.1 Stakeholders' Analysis of GM Crops

A stakeholder's Workshop on "Socio-economic Considerations for Genetically Modified (GM) Crops" was organized on May 26, 2015 at Department of Extension Education, PAU, Ludhiana in collaboration with the Division of Agricultural Extension, IARI, New Delhi under the project "Developing Guidelines & Methodologies for Socio-economic Assessment for Living Modified Organisms (LMOs), sponsored by the MoEF& CC, Govt. of India". Besides the scientists and extension professionals, the farmers and the representatives from NGOs, seed and input companies and media participated in the workshop.

During the discussion, farmers were found aware about the GM crop (here it meant Bt Cotton) but they lacked the knowledge about actual mode of action in this technology leading to many misconceptions in their minds. But they also felt that with the increase of population in India at rapid pace, growing of GM crops will be a necessity in the coming future. The farmers were also concerned about the high cost of seeds of GM crops. Some farmers perceived that the technology was more favourable to the seed companies as compared to the farmers in terms of profit. Farmers also expressed their choice for GM technology in terms of heat tolerance, drought tolerance and insect–pest resistance in crops like wheat, rice, pigeon pea and vegetables like okra and tomato. They perceived that the patent rights of GM crops were with the multinational companies and they sold seed at high costs to the farmers. The members of NGOs in the workshop were concerned about the biosafety measures in GM crops as they perceived that this technology might prove to be fatal for human health as there are carcinogenic contents in these crops and these also could cause allergies. The representatives from NGOs apprehended that there was surplus wheat and rice being stored in the godowns which were deteriorating without consumption so there was no need to go for GM crops and increase the cost of cultivation of the farmers. Farmers and NGOs were in favour of labelling the GM products so as to allow the consumers to know what they are eating. The extension personnel opined that regular monitoring of GM crops should be enforced as per the guidelines to ensure the biosafety in GM crops and data should be made available at public domains. The workshop emphasized on demystifying the misconceptions on GM crops through extension efforts. It was recommended that more awareness endeavours need to be made about GM crops by organizing focus group discussions at grass root level and activating district level committees for appraisal of GM crops. Farmer to farmer extension and farmers as resources persons could be used as methodology to make the farming community aware about the concept of GM crops.

The focus group discussions highlighted that the major socio-economic issues were related to risk perception; economic benefits; preferences; potential threat to livelihood systems, biodiversity and ecological set up; social and economic stability; institutional arrangements, business ethics and legal systems for safe and trustworthy deployment; and knowledge systems. There could be many more dimensions added to it. However, the stakeholders' opinions throw sufficient and insightful light towards the major socio-economic considerations, which may be taken into account while embarking upon biotech-led innovation systems.

The major assertions from the workshop included adoption of GM crops by the farmers to address food demand due to increasing population pressure in India; having affordable cost of the seed so that the farmers can take up GM crops; creating awareness about GM crops by organizing focus group discussions at grass root level;

activating district level committees for proper appraisal of GM crops; addressing health and environmental concerns before the release of GM cops; allocation of more funds to the public sector to ensure the biosafety measures and appropriate pricing of GM crops.

5.3.2 Understanding Farmers' Preference to GM Crops

Preference ranking method was used for identification of the decision parameters as well as evaluation of the biotech hybrids *vis-a-vis* conventional hybrids/varieties. For ensuring participatory assessment, farmers' criteria for varietal assessment were elicited and their prioritization was done with ranking. The farmers were asked to give weightage to their preferred criterion on score range of 0–10. Each criterion can be given a minimum value of zero and maximum value of 10.

Based on mean scores, the criteria were ranked. With the highest mean score of 9.67, the yield potential and efficacy in management of pests were considered as the first and foremost criteria for selection of any Bt. hybrid followed by the germination potential (MS:8.67); cost of seed (MS:8.50); plant type (MS:8.43); input requirement (MS:8.33); suitability to farm (MS:8.13), safety to human and cattle (MS:7.66), irrigation intensiveness (MS:7.33) and crop duration (MS: 6.67).

Preference ranking could also be used for differentiating the farmers' varietal preference individually or in group. Criteria-based ranking was used to understand farmers' comparative preference of Bt. cotton and non-Bt cotton hybrids.

Matrix of decision criteria with respect to selection and adoption of hybrids/varieties as well as the relative performance of different Bt hybrids and non-Bt hybrids/varieties was administered to 20 key informants individually as well as in groups. Ranking for the relative performance of the Bt hybrids and non-Bt hybrids/varieties against each criterion was done with scoring pattern of 0–10.

Assessment revealed the on field performance of the Bt cotton and non-Bt cotton hybrids based upon farmers' own experience. While Bt cotton performed exceptionally well on parameters like high yield, less number and cost of sprays, no incidence of American bollworm and suitability to heavy soils; the non-Bt hybrids were preferred to Bt cotton hybrids with respect to germination potential, ease of use, less input intensiveness and less susceptibility to stresses like physiological disorder, moisture stress, and incidence of secondary pests. Planting refuge lines was found highly cumbersome as the farmers had to prepare five different rows for sowing the refuge seeds and change the seeds in seed drills or resort to manual planting. Different Bt hybrids had different plant types, growth habits and canopy structure and accordingly crop geometry has to be adjusted. Such additional tasks made the farmers rate Bt cotton hybrids lower than non-Bt hybrids on criterion of complexity. The incidences of wilting and reddening of leaf baffled the farmers. These instances underline the importance of communicating whole technology packages to the farmers and not only the information on seeds alone. Mere seed cannot be a sufficient technology to assure production and profit. The farmers observed that Bt hybrids were irrigation intensive. The results were more discernable in Bt. cotton due to complete absence of incidence of bollworm.

The preference raking analysis provides the assessment in system's perspective rather than mere on economic gain.

5.3.3 Consumers' Preference Assessment: A Case of GM Wheat

A conjoint analysis based preference assessment was conducted. For the study purpose hypothetical case of Wheat was considered. An attempt was made with four attributes, namely—Type, Developer, Price and Nutritional value. The details of various levels of each of the product attributes are mentioned in Table 5.1.

For the current study purpose the term crop type was operationalized as the attribute of product which depicts whether the food crop is a pesticide free GM crop or pesticide sprayed GM wheat crop or pesticide sprayed non-GM wheat crop or pesticide free non-GM wheat crop. Similarly the term Food crop Developer was operationalized as the indicator of government/private entity participation in food crop variety development. Initial analysis of the data results in utility score estimates for each factor level which is also known as part-worth. They represent participants' preferences for a given level of attribute, with higher utility scores indicating greater preference for the given attribute level (Pullman et al. 2012).

Utility part-worth estimates for average income scenario were calculated based on the responses from the entire sample of 200 respondents, whereas the utility part-worth estimates for high, medium and low income groups were calculated by considering the responses exclusively from high, medium and low income groups, respectively.

Pesticide free non-GM, 20% lesser than normal price and 20% higher nutrition were the attribute levels with highest preference across all the income categories. This

Table 5.1 Selected attributes and their levels for the GM and Non-GM wheat crop

Attribute	Levels			
Crop type	Pesticide free GM wheat	Pesticide sprayed GM wheat	Pesticide sprayed non-GM wheat	Pesticide free non-GM wheat
Product price	20% higher than normal	Average price	20% lesser than normal price	–
Nutritional value associated with crop	20% higher nutrition	Average nutrition	20% lesser nutrition	–
Food crop developer	Government institutions	Private institutions	Collaboration	–

Source Author's own compilation

implies that product with combination of these three levels of attributes will be most preferred over the rest of combinations. Further in case of high-income category consumers, product developed through public-private collaboration were slightly more preferred over the products developed either by government participation only or by the private R&D entities alone. In contrary to this- in case of medium and low income categories high preference for food crops developed by government entities was observed over those developed either by private R&D entities alone or by government entities alone. The values of part-worth utilities in case of nutrition were negative. Whether the part-worth utilities get positive or negative value depends on the relation specified and the coding pattern. Since in our analysis we coded the attribute "Nutrition" in reverse order (with highest code value corresponding to lowest nutrition value) and we specified in the model that nutrition is assumed to be negatively related to preference hence it is same as assuming that preference is positively related to nutritional value when we have coded the variable "nutrition" direction of increase in nutrition level. So here negative values of the part-worth estimates confirm the negative association between reverse coded nutrition level and part-worth utility estimates. Hence we can conclude that part-worth utilities confirm the logic that preference scores are positively related with the level of nutrition.

5.3.4 Risk Perception Among Farmers About GM Crops

As risk refers to the possibility that adverse effects may occur as a result of natural events or human actions (Kates et al. 1985), risk perception can thus be defined as the subjective processing of sensory experiences and/or information about a potentially dangerous event or activity, and the evaluation of its seriousness, probability and acceptability (Sjöberg et al. 2004; Renn 2008). Risk perception as an inherently subjective assessment of uncertainties is internalized through social and cultural learning and is continuously modified by peers, media and other communication processes (Tulloch and Lupton 2003; Renn 2008).

Past studies indicate that perception and acceptance of biotechnology varies according to the type of application. This fact is obvious in the study conducted by Gaskell (2000) and Hoban 1998. Both of them found that there is stronger support for medical application of biotechnology than for agricultural applications. A study by Siegrist and Bühlmann (1999) analysed the differential risk perception about various applications of biotechnology in the domains of agriculture, food processing, drugs and medicine. Their findings suggested that nature of the application and the perceived benefits shape risk perception and the acceptance of biotechnology. Frewer et al. (2013) also indicated that different applications of genetic engineering are closely linked to perceptions of risk and benefit or need that are defined by the nature of each application. It is unlikely that, for most members of the public, attitudes towards the technology overall will define responses to specific applications. In addition, increasing the specificity of application types is likely to differentiate further public perceptions of risk and benefit. The results imply that public attitudes are defined by the processes associated with genetic engineering rather than the products of these processes. Almeida and Massarani (2018) in their research study on Risk-Benefit perception found perceived benefits like fall in production costs with the reduced use of agrochemicals, easier application of herbicides, better weed control and greater return on certain GM varieties, high degrees of satisfaction regarding GM soya even among producers whereas perceived risks like contamination of conventional crops, financial penalties for the producer, greater resistance of weeds to herbicides, uncertainties regarding the risks to health and environment posed by GMOs, loss of confidence in the scientific community, negative effect on the environment, dependency of farmers on biotechnology companies, end of traditional seeds, destabilization of country life, etc. They also analysed knowledge base of farmers where found duality in response like accepting medical uses of biotechnology due to their perceived benefits in specific uses but tend to make moral judgements and ethical consideration in use of biotechnology in broader terms. Majority intended to accept when found practical benefits but lack of understanding of the process of scientific concepts created opposite views.

Anderson et al. (2006) in their comparative study about stakeholders' risk perception about genetically modified foods and processes observed that biotechnological companies and farmers held the view that agro-biotechnology was advantageous to the environment while environmentalists and several consumers hold the negative view. This study supports the previous finding (Siegrist 2012) that distribution of benefits-risks plays an important role in shaping stakeholder's risk perception about agro-biotechnology. They also reported that risk perceptions are more prevalent due to lack of knowledge about the biotechnology and genetic modification. Role of risk-benefit distribution pattern and scientific know-how in shaping risk perception needs to be studied in Indian context.

A Likert-type scale was developed to measure the risk perception of the individual. Initially 60 statements were developed about living modified crops and related socio-economic, cultural and ecological concerns. Later with focus group discussions and analysis, 18 statements were retained. Each statement had response category on a five-point continuum ranging from "strongly agree" to "strongly disagree" with respective score ranging from 5 to 1. These set of statement were administered for responses by the farmers and scientists and research scholars.

A large majority of the farmers (76%) agreed, while 13% of them strongly agreed that GM crops like Bt cotton would be beneficial for farmers (Table 5.2). The recent set back due to outbreak of white fly in Punjab and Haryana where the farmers suffered colossal loss, had immensely affected their view about Bt cotton. However, the advantages had been so significant that they continue to repose faith in Bt cotton. Hardly 4% of them did not agree with the statement about its profitability.

More than 80% of them perceived that adoption of GM seeds would reduce the cost of cultivation and cultivation of GM crops would ensure food security for the rapidly growing population. Such perception has the base in the relief farmers had secured against the dreaded pest American Bollworm due to Bt cotton. There are concerns about gene flow and genetic pollution as a result of GM crops, but a large majority of farmers (75%) remained neutral as they had no convincing reason or

Table 5.2 Risk perception among farmers about GM crops

S. No.	Statement	Strongly disagree (f)	Disagree (f)	Undecided (f)	Agree (f)	Strongly agree (f)
1.	GM crops like Bt cotton will be beneficial for farmers	2 (0.9)	8 (3.6)	14 (6.4)	167 (75.9)	29 (13.2)
2.	Adoption of GM seeds will reduce the cost of cultivation	6 (2.7)	30 (13.6)	14 (6.4)	169 (76.8)	1 (5.0)
3.	Cultivation of GM crops will ensure food security for the rapidly growing population	4 (1.8)	20 (9.1)	2 (0.9)	191 (86.8)	3 (1.4)
4.	Cultivation of GM crops will be risky as pollen flow from GM plants will contaminate other neighbouring crops	0 (0.00)	22 (10.0)	165 (75.0)	33 (15.0)	0 (0.00)
5.	Since GM crops carry genes from different species they will cause harm to the human and cattle	0 (0.00)	25 (11.4)	135 (61.4)	50 (22.7)	10 (4.5)

(continued)

Table 5.2 (continued)

S. No.	Statement	Strongly disagree (f)	Disagree (f)	Undecided (f)	Agree (f)	Strongly agree (f)
6.	Entry of GM food in food chain should be stopped as they will lead to abnormality in body growth	0 (0.00)	26 (11.8)	103 (46.8)	85 (38.6)	6 (2.7)
7.	Cultivation of GM crops will harm agro-biodiversity	10 (4.5)	25 (11.4)	107 (48.6)	75 (34.1)	3 (1.4)
8.	The production and trade of GM seeds will increase the monopoly of big companies in the seed market	26 (11.8)	104 (47.3)	7 (3.2)	76 (34.5)	7 (3.2)
9.	GM technology is required for few crops	19 (8.6)	93 (42.3)	59 (26.8)	47 (21.4)	2 (9)
10.	Rigorous scientific testing is done prior to release of GM crops	12 (5.5)	13 (5.9)	18 (8.2)	164 (74.5)	13 (5.9)

(continued)

Table 5.2 (continued)

S. No.	Statement	Strongly disagree (f)	Disagree (f)	Undecided (f)	Agree (f)	Strongly agree (f)
11.	Genetic engineering scientists tend to conceal data about harmful effects of GMOs	67 (30.5)	74 (33.6)	63 (28.6)	16 (7.3)	0 (0.00)
12.	Only the large farmers will be benefitted by genetic engineering technology	22 (10.0)	69 (31.4)	8 (3.6)	119 (54.1)	2 (9)
13.	Promotion of GM technology will cripple indigenous knowledge system	14 (6.4)	34 (15.5)	20 (9.1)	150 (68.2)	2 (0.9)
14.	Promotion of GM crops should be banned as it will pose a serious threat to GI marked high value crops (eg Basmati rice)	12 (5.4)	25 (11.4)	22 (10.0)	160 (72.9)	1 (5.0)
15.	Genetically modified foods should be labelled for the benefit of consumers	0 (0.00)	0 (0.00)	93 (42.3)	107 (48.6)	20 (9.1)

(continued)

Table 5.2 (continued)

S. No.	Statement	Strongly disagree (f)	Disagree (f)	Undecided (f)	Agree (f)	Strongly agree (f)
16.	Information on biotechnology provided by mass media sources is trustworthy	0 (0.00)	11 (5.0)	93 (42.3)	100 (45.5)	16 (7.3)
17.	Deployment of GM crops will increase the cost of cultivation	19 (8.6)	68 (30.9)	91 (41.4)	32 (14.5)	10 (4.5)
18.	Prevalence of secondary pests will increase due to GM seeds	1 (5.0)	33 (15.0)	87 (39.5)	89 (40.5)	10 (4.5)

*The figures in parentheses are in percentage
Source Data collected from surveys

knowledge about it. A majority of them expressed similar view of neutrality to other risk concerns like "Cultivation of GM crops will be risky as pollen flow from GM plants will contaminate other neighbouring crops" or "Since GM crops carry genes from different species they will cause harm to the human and cattle" or "Entry of GM food in food chain should be stopped as they will lead to abnormality in body growth" or "Cultivation of GM crops will harm agro- biodiversity". This amply reflects the lack of understanding or facts among farmers to develop any perception. It shows the majority of protest is based on heresay or assumptions. More than 56% the farmers disagreed and about 37% agreed that the production and trade of GM seeds would increase the monopoly of big companies in the seed market. This perception has roots in mechanism of deployment of GM seeds. The farmers in initial years of deployment of Bt cotton had suffered due to high cost and accessibility. The supply was based upon advance indent and cash payment, which was unusual for the farmers. It reflects towards absence of policy guidelines about effective and farmer-friendly deployment mechanism. While the farmers have reposed faith in scientists about rigorous testing, they have expressed concern about indigenous knowledge system, GI marked high value crops (e.g. Basmati rice), being favourable for large farmers. The menace of secondary pest like white fly has given the farmers reasons to have alternative control measures. It was prudent at the part of women groups of Haryana who could check the loss through local solutions. The findings reveal that the farmers appreciate the gains but at the same time remain apprehended about unknown facts and undesirable consequences.

Major themes of perception:
Factor analysis was deployed to understand the major themes of perception. The scree plot and keeping the Eigen value more than one guided to extract four major factors that explained about 65% of variance. The scores obtained on each of the statements were subjected to factor analysis to identify a reduced set of variables, which could explain the domains of risk perception. The result of factor analysis was a rotated component matrix consisting of four components, which accounted for about 65% of variance.

Six items loaded for Factor 1, which relate to Gene flow- risk; Food chain risk; Loss of biodiversity; Resource rich biasness, Loss of ITK; and Increased threat of pests. It shows that the major domain of risk was threat to resource base like germplasm, knowledge, social network and stability. The farmers perceived undesired consequences as major risks.

Four variables which loaded onto Factor 2 signified scientific rigour in innovation development; Threat to Geographical Indication products; Right to options and fairness in deployment (labelling); and Trustworthiness of information source related to GM crops. These factors relate to governance, regulation and monitoring. Issues related to regulatory arrangement constitute the second important domain of risk perception.

The four variables, namely, Cost effectiveness of GM seed; GM seeds for food security, Health unfriendly foreign genes in GM seed, and Seed Monopoly were found to have higher factor loadings in Factor 3. It reflects that in farmers' perception seed is vital for livelihood systems. Accordingly, the four dominant variables clustering under factor 3 were grouped as seed system. Seed related issues are one of the predominant risks perception domains among the farmers. Factor 4 secured appreciable loadings from two items related to limited application of GM technology and non-transparency in innovation development process. The farmers believed that selection of the crops and the traits for transgenic development must be carefully and meaningfully planned and the results of experimentation should be available to public. Lack of Openness is the fourth major area of risk perception.

5.3.5 Risk Perception-Semantic Mapping

Many a times the variation in meaning attribution to an object, event, phenomenon or case, is observed, which could be analyzed with semantic mapping using semantic differential technique. A group of 20 women farmers were administered a set of 15 bipolar adjectives related to GM crops and their responses were elicited on an 11-point continuum (Table 5.3).

The plotting of the average score of women revealed their perception about GM crop. Since they had very recently witnessed colossal loss during the past few years

Table 5.3 Bipolar adjectives administered on an 11-point continuum

1. Beneficial ___:___:___:___:___:___:___ Non-beneficial
2. Successful___:___:___:___:___:___:___ Unsuccessful
3. Poisonous ___:___:___:___:___:___:___ Non-poisonous
4. Reliable ___:___:___:___:___:___:___ Unreliable
5. Costly ___:___:___:___:___:___:___ Cheap
6. Durable ___:___:___:___:___:___:___ Non-durable
7. Essential ___:___:___:___:___:___:___ Non-essential
8. Exceptional ___:___:___:___:___:___:___ Ordinary
9. Valuable ___:___:___:___:___:___:___ Worthless
10. Compatible___:___:___:___:___:___:___ Un-compatible
11. Destroyer ___:___:___:___:___:___:___ Constructive
12. Safe ___:___:___:___:___:___:___ Deadly
13. Farmer-friendly___:___:___:___:___: Unfriendly
14. Supportive ___:___:___:___:___:___:___ Non-supportive
15. Natural ___:___:___:___:___:___:___ Unnatural

Source Author's own compilation

in Bt cotton due to white fly, their responses were affected. The women considered GM crops as beneficial, durable, supportive and farmer-friendly. But at the same time they also considered it costly due to increase in cost of cultivation. Also they considered it poisonous as they believed that without containing some poisonous thing how an insect like American bollworm could be killed by a plant when the deadliest of pesticides were not effective. It reflected the inadequacy of knowledge among the women about the mode of action of *cry 1Ac* gene in plant system against the bollworm. Awareness and capacity building of the farmers must be stressed upon prior to deployment of such technologies.

5.3.6 Adoption Decision and Determinants

The synthesis of the adoption process presented by Feder et al. (1985) suggests that generally the level and quality of human capital affects the choice of new technologies in agriculture and for early adopters and for an efficient use of inputs, it plays a particularly positive role (Sheikh et al. 2003). Logit regression was deployed to identify the explanatory variables for willingness to adopt GM crops or living modified organisms. The positively significant coefficients of explanatory variables indicated their positive influence on adoption decision of farmers towards living modified crops. Age, number of family members engaged in farming, farming experience, social participation and social network were the major variables having a bearing on adoption decision among farmers. The probability of willingness to adopt living modified crops would increase by two, two and four times with one-unit increase in number of family members engaged in farming, social participation and social network of the farmers, respectively. However, size of holding and farming experience had negative bearing. One unit in these two variables would lead to reduction in willingness to adopt living modified crops. These factors could be considered while developing deployment and dissemination strategies for GM crops.

5.3.7 Will Transgenic or Living Modified Crops Lead to Economic Gains?

Economic return is the major criterion in decision-making in any venture and so is true in farming. In order to assess the economic gain, a comparative analysis of Bt cotton and non-Bt cotton was undertaken. There was significant difference in cost and benefit regimes of Bt and non-Bt cotton cultivation. The seed cost increased by about 2.7 times, but the farmers used higher seed rate. The cost also increased in irrigation. However, there was drastic fall (about 32%) in number of pesticide spray and cost on spray also reduced significantly. The yield increased by nearly 36%, while the benefit cost ratio increased by about 22%. The gains had been higher but because of incidence of white fly and other secondary pests there was increase in number of sprays and reduction in yield during the last season. A significantly higher benefit–cost ratio (1.98) for Bt cotton as against non-Bt cotton (1.62) showed the profitability of its cultivation.

Bansal and Arora (2015) in their research in Bt cotton economic analysis in India found that the effect of cotton prices on diffusion was positively significant whereas seed price was negatively significant. Srivastava and Kolady (2016) in research on Bt cotton impact on long-term growth in productivity at the national level in India found a positive and significant structural change in cotton yield growth during the post-*Bt* period. Steur et al. (2017) in their study on Willingness to Pay (WTP) for economic acceptance of consumers worldwide observed that consumers were willing to pay 23.9% more for GM biofortified food crops. Positive information (nutrition and GM benefits) was vital factor in highest consumer willingness to pay, compared with objective, negative and conflicting GM information. Steur et al. (2017) indicated a high WTP for GM biofortified foods. When information on vitamin levels or benefits was provided, consumers were prepared to pay a premium of 20%. Consumers' reactions towards GM crops were much more positive when direct consumer benefits were involved.

5.4 Conclusion

Innovations are critical for development, while seed is vital for livelihood. Therefore, any innovation in seed has wider implications. The emerging science of biotechnology has paved the way for genetic improvement with more preciseness and less time, while transcending those barriers which hinder conventional breeding. The merits apart, the acceptance of living modified organism is more dependent on socio-cultural milieu. The study made an attempt to analyze the socio-economic issues related to transgenic or living modified organism. Stakeholders' analysis was found to be effective in getting multidimensional impressionistic assessment in a quick and holistic manner. The major virtue is opportunity of on-spot cross validation and triangulation. It guided the selection of traits as well as the salient criteria and indicators for devising framework and methodology for socio-economic assessment. Besides capturing the cardinal data what is more critical is understanding the conditions, logic and heuristics of the farmers or other players based on which decisions were made and consequences were obtained. These findings help in insightful inferencing. Therefore, qualitative techniques must be used to complement the quantitative techniques. For example, the yield gain and savings on pesticides made the Bt cotton hybrids popular but at the same time the drudgery in refugia plantation and inappropriateness of several germplasm to suit the local conditions are the key considerations from farmers' point of view. Though farmers have expressed willingness to adopt the transgenic crops; the perception among the stakeholders is varied. In spite of having rich experience of cultivating Bt cotton; science communication and knowledge building process remained elusive. Does it mean that the innovations should be just a tool and the farmers are just to use them without enriching their own capital? Does such arrangements lay more focus upon business than holistic enrichment of society? Developing a perception map of an individual is essential to facilitate dialogue. With stimulus-response based assessment of perception through administration of statements did reveal the domains of risks but semantic differential tool was better to graphically demonstrate the mental map of people and get it triangulated and revised. Further, factor analysis was effective in classifying the layers of risk perception. It suggests the thematic area of risks being perceived among people. The questionnaire was found effective in preparing the socio-economic profile of the respondents. The set of questions provided empirical account of assets possessed, cropping pattern, capital owned, cost of cultivation, investment on fixed assets, seed and knowledge systems, information systems, etc. The cost of cultivation could provide the relative advantage of the innovation like Bt cotton. Decision-making among farmers are very crucial. What factors could have direct or indirect and favourable or unfavourable impact on decision-making could be understood with profiling through answers to questions framed like who takes decision; do seed dealers influence; what are the reasons for selecting a seed source; how far one has to travel to procure seed, etc. Logit regression could further delineate the explanatory variables for willingness to adopt. Conjoint analysis provided an objective assessment of trait preference of people.

Issues related to legal, ethics and governance, social implication of risks, economic production functions, risk–benefit analysis, social-cost benefit analysis need attention for closer examination of the socio-economic considerations to transgenic or living modified organisms.

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Chapter 6
Socio-economic Assessment of LMOs: An Ex ante Analysis of Insect Resistance and Herbicide Tolerance in Maize and Brinjal in Tamil Nadu

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Abstract Any technological development is embedded in and influenced by the social, economic, cultural and political settings. Hence socio-economic assessment of Living Modified Organisms (LMO) is a requisite step to understand the technology in a wider perspective. This study aims at socio-economic assessment of insect resistance and herbicide tolerance traits in maize and brinjal in Tamil Nadu. There is evidence of loss in yield and income due to insects and weeds. Salem District with maximum area under the selected crops was selected for the study and 60 farmers each cultivating maize and brinjal were surveyed. Percentage analysis and partial budget analysis were employed for data analysis. Economic valuation of improved LMO traits was done in an ex ante frame work. The reported yield loss due to weeds ranged between 11–40% in maize and 11–20% in brinjal. Chemical weeding was the most prevalent method of weed management in maize. Partial budget analysis revealed that the net economic benefit due to improved maize (LMO) with insect resistance and herbicide tolerance varies from Rs. 5028.62 to Rs. 13705.52 per hectare. In brinjal hybrids, net change in income per hectare due to insect resistance trait varies from Rs. 72,653 to Rs. 151,385. More than 90% of the farmers have cultivated GM Cotton and experienced higher yield and about 25% increase in income. The farmers desired to have herbicide-tolerant and insect-resistant maize hybrids and insect-resistant brinjal varieties.

Keywords LMO · Socio-economic assessment · GM crop · Economics · Ex ante

6.1 Introduction

Convention on Biological Diversity (CBD) adopted a decision on socio-economic considerations to develop conceptual clarity on socio-economic considerations arising from the impact of living modified organisms on the conservation and sustainable

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use of biological diversity in the context of paragraph 1 of Article 26 of the Cartagena Protocol on Bio safety (CPB). A Living Modified Organism (LMO) is defined in the Cartagena Protocol on bio safety as any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology. In agriculture biotechnology has been adopted rapidly to develop Genetically Modified (GM) crops with insect resistance, herbicide tolerance, to withstand drought, enhance nutritional quality, etc. Any technological development is embedded in and influenced by the social, economic, cultural and political settings. LMOs are no exception and socio-economic assessment is a requisite step to understand the technology in a wider perspective. The objectives of the study are developing and validating questionnaires for socio-economic assessment of Living Modified Organisms (LMOs), conducting field survey and development of guidelines and methodologies for socio-economic assessment of LMOs for selected crops in Tamil Nadu. Accordingly Tamil Nadu Agricultural University is involved in socio-economic assessment of insect resistance and herbicide tolerance traits in maize and insect resistance trait in brinjal.

6.1.1 Rationale for Selection of Crops

Maize: Maize, popularly known as "corn", is one of the most versatile emerging cash crops having wider adaptability under varied climatic condition. It is an important cereal in many developed and developing countries and also widely used for animal feed and as an industrial raw material. Its value chain is diverse from food to poultry feed to different industrial applications. Maize is one of the most widely distributed crops in the world. It is cultivated in tropics, sub-tropics and temperate regions. The major maize producing countries in the world are USA and China. India stands sixth in the global production though in terms of area it is in the fourth place because of low productivity. The maize productivity is the lowest among the top maize producing countries in the world. In India, maize is the third-most important food cash crop after wheat and rice. The compound growth rate (CGR) of area, production and productivity of maize in India showed positive growth rate from 1990s. During the period from 2000 to 2014 there is remarkable increase in the growth rate of area (2.68%), production (5.76%) productivity (3.00%) and area under irrigation (2.15%) in the cultivation of maize. In India the major maize producing states are Karnataka, Maharashtra, Andhra Pradesh and Madhya Pradesh accounting for nearly 50% of the area under maize and 55% of the production in the country.

Maize is one of most important industrial crops in Tamil Nadu produced mainly for poultry and cattle feed. The presence of large number of poultry farms in the state creates good demand throughout the year. The water requirement for the crop is very less which is an advantage for the water scarce regions of the State. The shorter duration of the crop is an added advantage to the farmers. Though Tamil Nadu is in 9th place in terms of maize area in India, It ranks first in productivity with a productivity level of 5450 kg/ha. The major maize producing districts in the state are Perambalur, Thoothukudi, Salem and Villupuram. Maize is cultivated in both irrigated and rain fed conditions in Tamil Nadu. Considering the importance of maize for ensuring farm income in the state and supply of raw material for feed industry the crop was selected for the study.

Brinjal (Eggplant): Brinjal is an economically important Solanaceous crop of sub-tropics and tropics and popularly called as eggplant. India is the second largest producer of brinjal after China with 13.44 million tonnes of production. But the productivity of brinjal in India is relatively lower compared to many other top brinjal producing countries. In India brinjal production is the highest in West Bengal and Odhisha. In Tamil Nadu, brinjal is grown under rainfed and irrigated conditions. It is a very popular vegetable among the people and grown across the state. A number of brinjal cultivars are grown in the state and the consumer preference depends upon fruit colour, size, taste and shape. In Tamil Nadu Krishnagiri and Salem are the top brinjal producing districts, accounting nearly 30% of the area in the State. Hence the crop was chosen for socio-economic assessment.

6.1.2 Rationale for Selection of Traits

6.1.2.1 Evidence of Huge Crop Losses Due to Insects: Insect Resistance Is a Desirable Trait

Maize: In India maize crop is attacked by about 139 species of insect pests with varying degree of damage. However, only about a dozen are quite serious (Sarup et al. 1987; Siddiqui and Marwaha 1993). Among them lepidopteron stem borers seriously limit maize yields by infesting the crop throughout its growth, from seedling to maturity. The yield losses caused by stem borers vary widely in different regions and range from 25 to 40% (Khan et al. 1997). De Groote et al. (2003) estimated that all stem borer species caused average annual losses of USD 80 million. Maize production is severely affected by maize stem borer to the degree of 15–60% and a loss of 24–75% has been reported (Kumar 2002). Farid et al. (2007) reported 10–50% damage by maize stem borer in Peshawar valley. Yield losses caused by stem borers in Africa are as high as 80% maize.

Brinjal: Brinjal is infested by more than 23 pests (Muthukrishnan et al. 2005) from the time of planting to harvest. A survey (Anonymous 2009) indicated that the key pest responsible for deterioration of quality and quantity in brinjal is shoot and fruit borer, aphid, jassid, epilachna beetle, and white fly. Among these pests, shoot and fruit borer is the key pest throughout Asia (Ghosh et al. 2003). Growers rely heavily on chemical pesticides to protect the crop. In India, shoot and fruit borer pest has a countrywide distribution and has been categorized as the most destructive and most serious pest causing huge losses in brinjal (Patil 1990). The larvae of this pest bore into the tender shoots right from the nursery bed and can cause yield loss. The different estimates of yield loss are 36–63% (Kumar and Singh 2012), 20–89%

(Raju et al. 2007), 21–80% (Singh and Singh 2001; Jhala et al. 2007), 84% (Eswara Reddy and Srinivasan 2004), 52–74% (Duara et al. 2003; Naitam and Markad 2003), 41–72% (Pareek and Bhargava 2003), 70–92% (Rosaiah 2001) 63% (Dhankar et al. 1997). The pest has been reported to inflict losses to the tune of 21–60% in Tamil Nadu (Raja et al. 1999), 70% in Andhra Pradesh (Sasikala et al. 1999), 80% in Gujarat (Jhala et al. 2007) and 41% in Himachal Pradesh (Lal et al. 1976). Pesticide misuse has adverse effects on the environment and human health and also increases the cost of production. Many farmers refrain from growing eggplant due to the cost of pesticides (Gapud and Canapi 1994).

6.1.2.2 Evidence of Huge Crop Losses Due to Weeds: Herbicide Tolerance Is a Desirable Trait

The estimates of production losses in maize due to competition from weeds are 30% (Rahman 1997), 40% (Kebede 2000) and (Oerke and Dehne 2004), 40–60% (Thobatsi 2009) and 60% (Akobundu 1987). Competition from uncontrolled weeds will result in yield losses of up to 70% (Rahman and James 1992; James and Rahman 1994). Yield loss is influenced by increase in the weed biomass, weed density and weed species (Blackshaw et al. 2002). Weeds not only cause severe crop losses but also require farmers and their families to spend a considerable amount of their time on weeding. More than 50% of labour time is devoted to weeding, and is mainly done by the women and children in the farmer's family (Ellis-Jones et al. 1993; Akobundu et al. 2002).

6.1.2.3 Advanced Stage of R&D on Insect Resistance and Herbicide Tolerance

Advanced Stage of R&D in insect resistance and herbicide tolerance is a prerequisite for release of new varieties of maize and brinjal with these traits. A recent study estimates insect resistance dominated among the transformation events in GM crops. Insect resistance trait dominated for crops already under commercial cultivation, pre-commercial stage, regulatory stage or at advanced R&D stage. It is also significant that the research for insect resistance is at advanced stage for maize and brinjal. For example, Parisi et al. (2016) observed that "the landscape of GM crop events in commercial cultivation or at the pre-commercial stage continues to be dominated by four arable crops: maize, cotton, soybeans and oilseed rape, similarly to the 2008 pipeline; fast followers include GM rice and potatoes, which are poised to reach the market soon and boast a dynamic pipeline of new events. A group of 'other crops' shows substantial growth and are reaching commercial cultivation and the pre-commercial stage. They include commercial herbicide-tolerant alfalfa, insect-resistant eggplant (Bt Brinjal) and a Chinese insect-resistant poplar. Hence the feasibility/likelihood of commercial release of insect resistance trait is high due to progress of biotech research on the selected traits and selected crops.

6.1.2.4 Relevance of Insect Resistance and Herbicide Tolerance in Tamil Nadu

Brinjal is one of the major vegetables crop affected by number of pests and diseases. The major pests include brinjal fruit and shoot borer, leafhopper, whitefly, thrips, aphid, spotted beetles, leaf roller, stem borer, blister beetle, red spider mite and little leaf disease. Farmers rely heavily on pesticides for management of pests and diseases. In maize, cost of engaging human labour for weeding is a major share in total cost of cultivation. The trait of insect resistance and herbicide tolerance would substantially reduce the cost of cultivation and enhance the ease of crop cultivation. Hence these two traits were selected for the study.

6.2 Methodology

6.2.1 Conceptual Framework

6.2.1.1 Economic Assessment of LMOs: Trait Valuation

In agriculture LMOs are developed primarily to improve crop yields through desirable traits. The process of identifying and describing the benefits of a trait and attaching a value to it is a complex process. The serious issues faced by the farmers in the state are the incidence of weeds and pests like stem borer in maize and shoot and fruit borer in brinjal. The study tried to study whether the proposed LMO variety with the traits that reduce the incidence of pests and weeds could be having any economic benefits for the farmers. In this study the trait valuation was attempted in an *ex ante* situation with no available data on the performance of the proposed traits in the selected crops.

6.2.1.2 Methods of Trait Valuation

Researchers have adopted different approaches in assessing a trait value. Selection of particular method depends on the nature of data available, trait(s) in consideration, purpose for which valuation is done, etc. The methods are described below.

- Direct measurement of all costs and benefits associated with the crop production after the introduction of the technology. Accounting individual costs of inputs other than one in consideration will provide the residual cost which can be ascribed to that particular input such as trait. The increase in yield over the existing technology is the added benefit. Sum of these two net benefits will form the value of the trait. This method accounts for the costs and benefits associated with the trait under consideration. This method is known as Partial Budget Analysis (PBA). The method is explained in detail below.

- Using a choice experiment approach, one can investigate farmers' crop variety preferences, estimate the mean willingness to pay for each crop variety attribute, and also identify household specific and institutional factors that govern the preferences. Often hedonic price model is used to estimate the willingness to pay for a particular crop trait.
- Economic Surplus Model has been widely used to estimate the potential benefits that could result from commercialization of crop improvement process involving new traits.

6.2.1.3 Partial Budget Analysis (PBA)

Farm activities are often associated with changes in the crop enterprises or in the use of technologies. When a farmer contemplates changes in the use of technology like the use of LMOs, PBA can be used to analyse the anticipated costs and benefits of the LMOs. This PBA analysis is simple and convenient tool for cost benefit analysis when there is no data on the anticipated technology with suitable assumptions. In an ex ante framework, partial budgeting is a statement of anticipated changes in costs, returns and profits. It considers those factors that are changed. The potential of the introduced change in the farm process is evaluated for its incremental effects using this technique.

In this study, the cost and benefit of existing cultivated varieties of maize and brinjal are compared with GM maize having the traits of insecticide resistance and herbicide tolerance. In calculating partial budgets, the costs (debit side) and benefits (credit side) due to contemplated changes are estimated. The elements of a partial budget are: added or reduced costs, and added or reduced returns. In working out partial budgets, we analyze the costs (debit side) and benefits (credit side) arising from the contemplated changes.

a. Debits: What loss of present revenue occurs? What extra new costs are incurred?
b. Credits: What new extra revenue is obtained? What present costs are no longer incurred?

Credit = Added returns + Reduced costs
Debit = Reduced returns + Added costs
Net Benefit = Credit – Debit
A positive change in the net benefit indicates the beneficial technological change. In this chapter PBA is employed for assessing the economic impact of LMOs at the farm.

6.2.2 Sampling and Data

Sampling framework for data collection w*a*s designed based on the criteria of maximum area of the selected crops cultivated in the state. Salem District grows maxi-

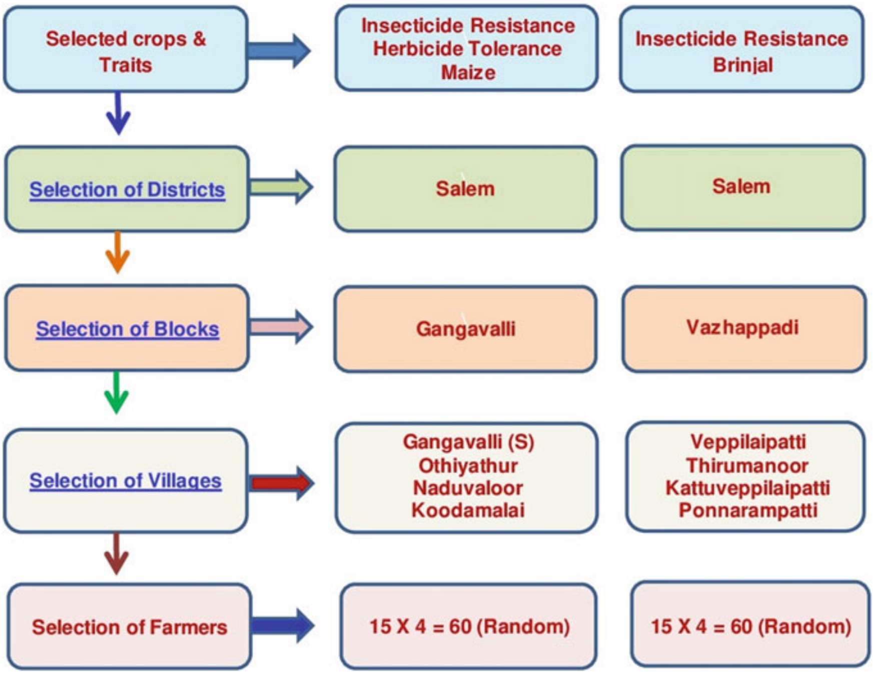

Fig. 6.1 Schematic diagram of sampling framework. *Source* Author's own compilation

mum area of irrigated maize and brinjal and hence Salem District was selected for the study. The average maize area for the triennium ending 2013–14 was 25,459 ha accounting for 19% of State area and average brinjal area for the same period was 1482 ha accounting 15% of the total area in the state. The scheme of data collection framework is summarized in Fig. 6.1.

Blocks and villages were selected based on the maximum area of the selected crops in the district. Farmers were selected at random at the rate of 15 each from each of the selected villages, thus a total of 60 maize farmers and 60 brinjal farmers were selected for the survey.

6.3 Results and Analysis

6.3.1 Socio-economic Background of Farmers

Majority of the maize farmers, accounting 60% of the total are in the age group of 36–50 years. Almost 65% of the farmers are educated up to eighth and only 5% have completed their education up to 12th class. The average family size of the sampled respondents was 3.50 out of which average numbers of people engaged in farming are an average of 2.58. Almost 42% of the sampled respondents have 2–10 years of experience in LMO (Living Modified Organism) farming. Among the remaining; 17% of the farmers have an experience from 1 to 5 years followed by 15% with an experience in LMO farming for greater than 10 years. The left-over 26% have no experience in LMO. Among the 60 sampled respondents, 32 farmers (53.33%) had 21–30 years of experience in farming.

Among the brinjal farmers 52% fall under the age category of 36–50 years and 65% of the 60 farmers educated up to eighth class. The average family size is 4.05 and the average number of people engaged in farming is 4.75. Among the 60 sampled farmers, 61.67% of the farmers are experienced in LMO farming. 30 farmers had the experience in farming for less than 20 years and 19 of them were experienced for 21–30 years and the rest of them had an experience of more than 30 years in farming.

6.3.2 Land and Water Resources

All the farmers were cultivating their owned land with 61.66% of farmers cultivating in red soil followed by 38.33% in sandy loam soil. The major source of irrigation was open well as well as tube well (78.33%) followed by tube well (21.66%). All the sampled farmers owned a tube well as well as a pump set, while farmers owning tractor and tractor implements and cattle were only 20% and 27% respectively. Among the farm assets, the value of tube well was the highest (Rs. 3.67 lakhs) followed by tractor (Rs. 3.02 lakhs). The pump sets and cattle had an average value of Rs. 0.49 lakhs and Rs. 0.33 lakhs respectively.

All the 60 farmers are cultivating brinjal in their owned land. The major soil type is sandy loam soil and irrigation is mostly through open well as well as tube well (68.33%). The average value of the assets like tractor is Rs. 357,600 followed by Rs. 313,476 for tube well. Tube well and pump set is used by all the sampled farmers.

6.3.3 Cropping Pattern in Sample Farms

In the Kharif season the major crops grown are maize (100%), cotton (35%), paddy (33.33%), tapioca (25%) and turmeric (21.66%). In a total area of 535 ha of sample farmers; almost 320 ha of the area is under maize cultivation followed by cotton, paddy, tapioca and turmeric which are grown in 84, 60, 45 and 26 ha respectively. The per cent of area under maize increased by 7.5% in Rabi season and the average yield also increased by almost 3 quintals per hectare in the season.

Brinjal, Maize, Turmeric, Cotton, Paddy and tapioca are the major crops cultivated among the brinjal farmers in both Kahrif and Rabi seasons. In a total area of 736 ha in the Kharif season, Brinjal is cultivated by all the sampled respondents in a total area of 136 ha (18.47% of total cultivated area) and 189 ha (25.67% of total cultivated area) in Rabi season.

6.3.4 Choice of Varieties and Hybrids Grown

Maize

The maize hybrids grown in Kharif and Rabi seasons are almost identical. 30 per cent of the farmers cultivate NK 6240 variety in both Kharif and Rabi season mainly because of higher price fetched by the variety. The variety Gargil 900 Gold is cultivated by 15% of the farmers in Kharif and 12% of the farmers in Rabi. 13 and 7% of the farmers cultivate CP 818 variety in Kharif and Rabi respectively. The highest priced variety NK 6668 is grown by 8% in both the seasons. Other major varieties cultivated by the sampled farmers are PIONEER 3546, CP 828, pioneer 828, AP 244, etc. Cauvery Super 252 variety is mainly cultivated in Rabi season. The average quantity of seed in Kharif and Rabi season is 19.92 and 19.06 kg/ha respectively with an average price of Rs. 225.76 and Rs. 219.06 per kg respectively. All the 60 farmers are procuring seeds from the dealers in the market mainly because of good seed germination quality (92%). The farmers pointed that the choice of varieties was based on its high yield, good germination (100% of the farmers) and also its quality grains and higher grains filling (100%). In the choice of hybrids, 82% of the farmers chosen the hybrid on their own while the remaining 18% of the farmers were advised by private companies and the seed dealers. 62 per cent of the farmers pointed persuasion by the dealers in the selection of the hybrids. Majority of the farmers (83%) purchased the seeds by paying cash while the remaining 13 purchased on credit.

Brinjal

In brinjal farmers mostly grew local varieties rather than hybrids in both the seasons. In Kharif season 77% and in Rabi 85% of farmers grown local varieties of brinjal the rest of the farmers grown brinjal hybrids. The major varieties cultivated in both the seasons are Attur green, Parul, Ujala gold, Indamjeeva, Mahy 91, Hareli, etc. Attur green is the major variety which is a local one and almost 85% of the farmers cultivating the variety in both kharif and rabi seasons. Among the brinjal farmers, 58.33% of the farmers are purchasing seeds from seed seller and 20% of them are obtaining the seeds from the nearby farmers and the rest of them are using own seeds. The average quantity of (variety) seeds used for brinjal cultivation is 365.71 g/ha in Kharif season and 370.10 g/ha in Rabi season. Good germination capacity and high yield along with quality fruits are the major factors influencing the selection of a variety. 95 percent of the farmers purchase the seeds by cash.

6.3.5 Weed Incidence and Management

Maize

All the farmers reported the incidence of the weeds in maize cultivation. 77 per cent of the farmers stated that the incidence was of medium level, while 23% of the farmers faced high level of weed incidence on their fields. 53 out of the 60 farmers reported the incidence of weeds during the vegetative phase of growth of maize while the remaining seven farmers confronted the incidence of weeds during the flowering stage of maize. Most of the farmers (85–95%) reported a yield loss of 11–40% during kharif and 11–20% during Rabi. Chemical weeding (85%) was the most prevalent method of weed management among the sampled farmers followed by manual weeding (77%). 30 per cent of the farmers resorted to summer ploughing to prevent the weed incidence. Atrazine under the brand name Dhanuka Dhanuzine (18 farmers) and Atrataf (14 farmers) and Accord (8 farmers) are the most commonly used weedicides by the farmers in the kharif season. Atrazine is also used under other brand names like Agnes, Atranax, Rasayanzin, Crozin, azarin, Atrastar and Surya. The average quantity of atrazine used was 1.32 kg/ha at an average price of Rs 378.10 in Kharif season. Major brands of 2,4 D used in the Kharif season are weeder (15 farmers), Weednash, Podium and Gilltwo. On an average 1.29 kg of 2,4 D is used per ha of maize at a cost of Rs. 382.50. In Rabi season 1.23 kg/ha of Atrazine is used as preemergence.

The post emergence weedicides used in Rabi season are 2,4 D under the brand names weednash, gilltwo, D-cell, superhit, weeder,, podium Agnes and Atranax, The average quantity of 2,4 D sprayed is 1.2 kg/ha at an average price of Rs 360.83 per hectare. Atrazine and 2, 4 D are used within three days after sowing.

Brinjal

All the 60 farmers reported the incidence of weeds every season. 93 per cent of the farmers opined that the incidence of weeds was major in the vegetative stage of brinjal. The yield loss reported due to weeds was 11–20%. Farmers practiced chemical and manual method of weeding; besides 75% of them followed summer ploughing. The major pre-emergence herbicides used in Kharif and rabi seasons are Pendimethalin and oxyflourfen under different brand names. The average quantity of pre-emergence herbicide used in kharif season and rabi season are 2110.24 ml/ha and 2185.40 ml/ha respectively. In value terms, the average value of herbicide usage in Kharif and rabi are Rs. 1674.42 and Rs. 1740.05 respectively. The major post emergence herbicides used in kharif and rabi season are Quizalofop ethyl under different brand names.

6.3.6 Pests Incidence and Management

Maize

The major pests infesting maize crop are stem borer with 100% incidence followed by cob worm (43%) and stem fly (22%). The severity of incidence was low to medium for all the major pests. Among the minor pests, aphids and red spider mites were reported by 32 and 10% of the farmers respectively. The severity of the minor pests also ranged from low to medium level. Chemical methods and summer ploughing were the common methods of pest control followed by the sampled farmers. 78% of the farmers adopted chemical methods to control the pests while 30% of the farmers performed summer ploughing as a method of pest control.

The major pesticides used for stem borer management in the kharif season are Monocrotophos (Phoskill), Cartap hydrochloride (Caldan 50 SP), Indoxacarp (Avunt), Chlorantraniliprole 18.5% SC (Coragen), Thiodicarb 75% WP (Larvin), Emamectin Benzoate (Elpida). The average quantity and price of the pesticides used for stem borer management is 482 ml/ha and Rs. 829 per hectare. The insecticides used are systemic, contact and stomach poisons in nature. The chemicals used for stem borer and cob worm management in maize during the Rabi season are Monocrotophos (Phoskill), Methomyl 40% SP (Lanate), Monocrotophos (Monovip), etc. The average quantity and price of these chemicals are 511 ml/ha at Rs. 729.66.

Brinjal
The major pests that infest the brinjal crop reported by all the 60 farmers are shoot and fruit borer and the leaf hopper. Other pests like stem borer and epilachna beetle are also found infesting the crop but the severity of the incidence is low. The minor pests that infest the brinjal are white fly, thrips and red spider mites and among these the red spider mites incidence is reported by 75% of the farmers. The major methods of pest management followed by the sampled farmers are chemical methods and summer ploughing.

All the farmers are following chemical method of pest management in brinjal. Among the major pests, the shoot and fruit borer is the major pest that needs major attention in chemical control. The major chemicals applied to management shoot and fruit borer in kharif and rabi seasons are Triazophos 40 EC, Novaluron 10% EC, Cartap hydrochloride 50% SP, Spinosad 45 SC etc. Among these chemicals, the Spinosad 45 SC costs Rs. 15,098 (885.00 ml) per hectare. The average value of pesticide used for shoot and fruit borer management is Rs. 33801.89 for Kharif season and Rs. 38092.57 for rabi season. Similarly, Rs. 1287.50, Rs. 5034.76, Rs. 6106.08 is spent for chemical management of Epilachna beetles, sucking pests and disease management respectively in Kharif season. The average amount spent in rabi season for the same is Rs. 1481.30, Rs. 7364.31 and Rs. 5328.33 respectively.

6.3.7 Cost of Cultivation

Maize
The total cost of cultivation per hectare is Rs. 59,803 in Kharif season and Rs. 60,179 in Rabi. Even though the cost is slightly higher for Rabi season, the profitability is more for Rabi maize as indicated by the higher net income of the Rabi maize (Rs. 38,434) than the Kharif maize (Rs. 26,966). The average yield as well as the gross income for the Rabi maize (8050 kg/ha and Rs. 98,612 respectively) is higher than that of Kharif (7775 kg/ha and Rs. 86,769 respectively). The herbicide usage in value terms for Kharif maize is Rs. 760 which is higher than that of rabi maize (Rs. 723). The cost involved in stem borer (the major pest affecting maize) management is lower for rabi maize. The percentage share of each component to the total cost of cultivation is highest for labour (48%) followed by fertilizers (27%), seed and

machine labour for both Kharif and Rabi maize. The detailed description of various cost items of the maize is given in Appendix 1.

Brinjal

The total cost of cultivation of brinjal varieties per hectare was estimated as Rs. 397,784 in Kahrif season and Rs. 398,159 in Rabi season. The major component of the cost of cultivation in both seasons is the labour cost (72%) followed by cost involved in insecticide usage for the control of shoot and fruit borer in brinjal which is the major damaging pest in the brinjal crop. A high cost of Rs. 33,801 (8.50%) and Rs. 38,092 (9.57%) is spent only for shoot and fruit borer management in Kharif and Rabi season respectively. Evolving a GM variety with insect resistance would reduce the cost involved in shoot and fruit borer management. The estimated cost of cultivation of hybrids in brinjal was Rs. 442,264 per ha in kharif and Rs. 445,970 in Rabi season. There is not much variation in the cost of shoot and fruit borer management between seasons or between local variety and hybrids cultivated in the study area. The detailed cost estimates are given in Appendix 2.

6.3.8 Economic Benefits of GM Crops (LMO): Partial Budget Analysis

In maize farmers face loss due to pests and incur higher cost for removing weeds. In this context research on genetic modification of maize for both insect resistance and herbicide tolerance is being undertaken. An attempt is made to estimate the net benefits to farmers if they choose to cultivate GM maize with insect resistance and herbicide tolerance through partial budget analysis. In this approach, labour cost saved in weeding, yield loss prevented due to insects and higher seed cost paid for GM technology are accounted. In maize crop the net economic benefit due to improved maize (LMO) with insect resistance and herbicide tolerance, varies from Rs. 5028.62 to Rs. 13705.52 per hectare in kharif season and from Rs. 5549.05 to Rs. 15410.31 in Rabi season with an assumed yield increase from 5 to 15% and 20% increase in seed cost (Table 6.1).

In brinjal the genetic modification is mainly aimed at insect resistance against the pest shoot and fruit borer. Farmers in the study area cultivate both local varieties of brinjal and hybrids. The economic benefit due to improved brinjal variety and brinjal hybrid with insect resistance was estimated separately because the input use, yield and profit vary widely between variety and hybrid. The increase in income due to improved brinjal variety with insect resistance varies from Rs. 63,668 to Rs. 123,509 per hectare in kharif season and from Rs. 64,441 to Rs. 117,247 in Rabi season withan assumed yield increase from 5 to 15% and 20% increase in seed cost (Table 6.2). In the case of brinjal hybrids net change in income per hectare due to insect resistance trait varies from Rs. 72,653 to Rs. 151,385 in Kharif season and Rs. 74,666 to Rs. 148,838 in Rabi season with an assumed yield increase from 5 to 15% and 20% increase in seed cost (Table 6.1).

Table 6.1 Economic benefits of GM crops (LMO): partial budget analysis

Details		Maize—hybrid		Brinjal—variety		Brinjal—hybrid	
		Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
I	*Benefits due to LMOs (Credit)*						
A	Increased yield over existing crop (value)	4338	4931	29,921	26,403	39,366	37,086
B	Reduction in costs						
	1. Value of reduced herbicide use	761	724	0	0	0	0
	2. Value of reduced pesticide use	829	730	33,802	38,093	33,802	38,093
	Sub total (B)	1590	1453	33,802	38,093	33,802	38,093
II	*Costs due to LMOs (Debit)*						
C	Added cost for LMO seeds	899	835	55	55	514	512
D	Reduced income due to LMOs	0	0	0	0	0	0
III	*Total credit (A+B)*	5928	6384	63,722	64,496	73,168	75,178
IV	*Total debit (C+D)*	899	835	55	55	514	512
V	*Net benefit (III–IV)*	5029	5549	63,668	64,441	72,653	74,666
VI	*Sensitivity of net benefits to varying assumptions*						
	5% Yield increase and 20% increase in seed cost	5029	5549	63,668	64,441	72,653	74,666
	10% Yield increase and 20% increase in seed cost	9367	10,480	93,588	90,844	112,019	111,752
	15% Yield increase and 20% increase in seed cost	13,706	15,410	123,509	117,247	151,385	148,838

Source Data collected from surveys

6.3.9 Major Constrains in Cultivation

All the maize farmers emphasized the rising cost of inputs and the incidence of weeds as the major constraint. Low price for the output and lack of availability of labour was a major difficulty for more than 80% of the farmers. Other problems faced by the farmers were incidence of pests and diseases (43%), soil problems like salinity and alkalinity (18%) and the quality of seeds (20%) available in the market. All the brinjal farmers had reported the rising cost of inputs, increased pests, disease and weed incidence and low price of the output as a major constraint in cultivation. Other factors that are constraining the brinjal cultivation are availability of labour, availability of quality seeds and the problematic soils in the area.

6.3.10 Knowledge and Perception on LMOs

All the Maize farmers and 93% of Brinjal farmers were aware about GM Cotton. More than 90% of both the farmers have cultivated GM Cotton and experienced higher yield for GM cotton. Most of the farmers noticed around 25% increase in income due to GM Cotton cultivation. All the Maize farmers desired to have herbicide tolerance and insect resistance in maize hybrids. In brinjal 75% of the farmers desired to have a shoot and fruit borer resistance in a brinjal variety. Both the categories of farmers desired to have GM trait against Sucking and Lepidopteral pest and herbicide tolerance. The farmers in general did not have any idea on adverse effect of GM crops on human, on livestock or on environment. All the Maize farmers and 77% of Brinjal farmers were willing to adopt proposed GM crop with desired traits. Farmers are willing to pay extra cost up to 25% in Maize and 30% in brinjal with desirable traits. Most of the farmers experienced for 22–30 years the traits under study, pest incidence and weed problem, and expect 25% increase in yield in Maize and 50% in Brinjal if the problem is addressed.

6.4 Conclusion

LMOs offers enormous scope for increasing food production and enhancing agricultural productivity to feed the growing population and ensuring remunerative farm income to millions of small farmers. Productivity gained in the last 20 years through biotech crops also proves that conventional crop technology alone cannot allow us to feed the immense increase in population, but neither is biotechnology a panacea. The global scientific community adheres to the option that a balanced, safe and sustainable approach using the best of conventional crop technology such as the well-adapted and agronomically desirable and high-yielding germplasm, and the best of biotechnology (GM and non-GM traits) to achieve sustainable intensification of crop productivity on the 1.5 billion hectares of cropland globally (ISAAA 2016). The present study in an ex ante frame work attempts socio-economic assessment of LMOs, viz., insect resistance and herbicide tolerance traits in maize and insect resistance trait in brinjal in Tamil Nadu.

Majority of the maize farmers are middle aged, in the age group of 36–50 years. Nearly half of the surveyed farmers had previous experience of cultivating an LMO (GM cotton). The cropping pattern of the study area shows that along with maize and brinjal farmers also grow crops like cotton, paddy, tapioca and turmeric. Criteria for selection of varieties or hybrids include high yield, good germination, quality grains and higher grains filling. All the farmers reported the incidence of the weeds in maize and brinjal cultivation. Most of the farmers reported a yield loss of 11–40% during kharif and 11–20% during Rabi in maize. Chemical weeding (85%) was the most prevalent method of weed management among the farmers. In brinjal the yield loss reported was 11–20%. Farmers practiced chemical and manual method of weeding.

The major pests infesting maize crop are stem borer with 100% incidence followed by cob worm (43%) and stem fly (22%). Chemical methods and summer ploughing were the common methods of pest control followed by the farmers. The average quantity and price of the pesticides used for stem borer management is 482 ml/ha and Rs. 829 per hectare. The major pests that infest the brinjal crop are shoot and fruit borer and the leaf hopper. The major methods of pest management followed by the sampled farmers are chemical methods and summer ploughing.

The total cost of cultivation of maize per hectare is Rs. 59,803 in Kharif season and Rs. 60,179 in Rabi. Cost of labour and fertilizers constitutes the major share in total cost. The total cost of cultivation of brinjal varieties per hectare was estimated as Rs. 397,784 in Kahrif season and Rs. 398,159 in Rabi season. The estimated cost of cultivation of hybrids in brinjal was Rs. 442,264 per ha in kharif and Rs. 445,970 in Rabi season. Partial budget analysis revealed that the net economic benefit due to improved maize (LMO) with insect resistance and herbicide tolerance, varies from Rs. 5028.62 to Rs. 13705.52 per hectare in kharif season and from Rs. 5549.05 to Rs. 15410.31 in Rabi season with an assumed yield increase from 5 to 15% and 20% increase in seed cost. In the case of brinjal hybrids net change in income per hectare due to insect resistance trait varies from Rs. 72,653 to Rs. 151,385 in Kharif season and Rs. 74,666 to Rs. 148,838 in Rabi season with an assumed yield increase from 5 to 15% and 20% increase in seed cost.

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Appendix 1

See Table 6.2

Table 6.2 Cost of cultivation of maize

Details		Kharif			Rabi		
		Qty	Value (Rs)	%	Qty	Value (Rs)	%
1	Labour (man days and women days)/ha	117.00	29000.00	48.49	117.00	29000.00	48.18
2	Machine labour (h/ha)	5.75	4150.40	6.94	6.40	5030.40	8.35
3	Seed (kg/ha)	19.92	4497.13	7.51	19.06	4175.28	6.93
4	Fertilizer use/ha						
	A. Organic fertilizer (farm yard manure)	4000.00	2400.00	4.01	Nil	Nil	
	B. Inorganic fertilizers	1077.65	14154.18	23.66	1201.60	16325.00	27.12
5	Herbicide						
	A. Atrazine (kg/ha)	1.32	378.10	0.63	1.23	363.00	0.60
	B. 2.4 D (kg/ha)	1.29	382.50	0.63	1.20	360.83	0.60
6	Insecticide (g/ml/ha)						
	A. Stem borer and Cob worm management Insecticides	481.66	829.00	1.38	510.83	729.66	1.21
	B. Other pests Mgt insecticide	598.33	215.00	0.35	641.66	270.41	0.44
7	Baging (no. of bags)	77.75	2079.81	3.47	80.50	2185.57	3.63
8	Transportation		1716.62	2.78		1738.80	2.88
9	Total cost		59802.76			60178.54	
10	Average yield (kg/ha)		7775.00			8050.00	
11	Gross income		86769.00			98612.50	
12	Net income		26966.24			38433.96	

Source Data collected from surveys

Appendix 2

See Table 6.3.

Table 6.3 Cost of cultivation of brinjal

Details		Local variety						Brinjal hybrid					
		Kharif			Rabi			Kharif			Rabi		
		Qty	Value (Rs)	%	Qty	Value (Rs)	%	Qty	Value (Rs)	%	Qty	Value (Rs)	%
1	Labour (man days + women days)/ha	1176.09	289716.00	72.83	1171.91	293672.00	73.76	1210.92	290072.00	65.59	1196.70	289648.00	64.95
2	Machine labour (h/ha)	6.41	5459.58	1.37	6.25	4789.06	1.20	7.10	5866.02	1.33	5.90	4666.68	1.05
3	Seed (g/ha)	365.71	273.44	0.07	370.10	276.72	0.07	186.20	2571.44	0.58	197.70	2560.11	0.57
4	Fertilizer												
	A. Organic fertilizer (FYM) (kg/ha)	20000.00	12000.00	3.02	–	–	–	22000.00	14190.00	3.21	–	–	
	B. Inorganic fertilizer (kg/ha)	1260.65	18618.58	4.68	1201.60	19325.00	4.85	1441.05	19619.65	4.44	1430.97	19121.04	4.29
5	Herbicide												
	A. Pre emergence (ml/ha)	2110.24	1674.42	0.42	2185.40	1740.05	0.44	2110.24	1674.20	0.38	2185.40	1740.05	0.39
	B. Post emergence (ml/ha)	879.04	1420.09	0.36	865.83	1274.20	0.32	879.04	1420.09	0.32	865.83	1274.20	0.29

(continued)

Table 6.3 (continued)

Details		Local variety						Brinjal hybrid					
		Kharif			Rabi			Kharif			Rabi		
		Qty	Value (Rs)	%	Qty	Value (Rs)	%	Qty	Value (Rs)	%	Qty	Value (Rs)	%
6	Insecticide												
	A. Shoot and fruit borer pesticides (ml/g/ha)	6034.35	33801.89	8.50	6047.43	38092.57	9.57	6034.35	33801.89	7.64	6047.43	38092.57	8.54
	B. Beetles—pesticides (ml/g/ha)	1375.00	1287.50	0.32	1496.66	1481.30	0.37	1375.00	1287.50	0.29	1496.66	1481.30	0.33
	C. Sucking pest—Mgt pesticides (ml/g/ha)	3741.63	5034.76	1.27	3919.97	7364.31	1.85	3741.63	5034.76	1.14	3919.97	7364.31	1.65
7	Fungicides (ml/g/ha)	6420.95	6106.08	1.54	6616.66	5328.33	1.34	6420.95	6106.08	1.38	6616.66	5328.33	1.19
8	Bagging (no. of bags)	351.80	10782.67	2.71	378.00	11434.50	2.87	938.40	27776.64	6.28	1043.20	32965.12	7.39
9	Transportation		11609.40	2.92		13381.20	3.36		32844.00	7.43		41728.00	9.36
10	Total cost		397784.40			398159.20			442264.27			445969.71	
11	Yield (kg/ha)		17590.00			18900.00			46920.00			52160.00	
12	Gross income		598411.80			528066.00			787317.60			741715.20	
13	Net income		200627.40			129906.80			345053.33			295745.49	

Source Data collected from surveys

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Chapter 7
Socioeconomic Assessment of Potential LMO Adopters in Gujarat

N. Lalitha

Abstract This chapter is focused on an *ex ante* scenario of farmers adopting drought- and saline-resistant GM varieties in ground nut and castor. For the chosen farmers farming is the main source of livelihood and majority of them had access to irrigation. Majority of the castor and ground nut cultivators reported experiencing salinity and drought affecting their production in the last 5–10 years though such conditions have been prevalent for more than 40 years. The study attempted production scenarios with and without traits and also constructed benefit cost scenarios at increased price of seeds and yield levels with new traits. Farmers were more familiar with Bt cotton and brinjal than any other crops. Majority of the farmers were willing to use the new variety with the desired trait and expected their LMO output to be priced at least 1.25–1.5 times more than the present level of prices. 98 percent of the farmers were willing to pay 10–50% higher price for the variety with new GM traits. Majority of the farmers agreed that GM crops are beneficial for farmers and the GM technology is required for a few crops as it tends to reduce the cost of cultivation. While most of the farmers did not think that GMOs pose an environmental risk, yet they were vary of their view on the GM pollen contamination. Farmers also expressed fears about the scientific information about GMOs. This signals that there is a need for the scientists to communicate frequently to the farmers about the LMOs through extension services.

Keywords Castor · Ground nut · GM · Drought · Salinity · Trait adoption

7.1 Rationale of the Study

Several initiatives were undertaken by the Ministry of Environment, Forests and Climate change (MoEFCC), Government of India to develop methodologies and guidelines for the socio-economic (SE) evaluation of LMOs for environmental release for cultivation and entry into the food chain of animals/humans. For the SE evaluation of

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LMOs before the environmental release for cultivation, several studies were launched through the efforts of RIS and MOEFCC and one of the studies was undertaken by Gujarat Institute of Development Research, Ahmedabad. This study was undertaken to provide an ex ante SE assessment of farmers in Gujarat, a state which led the rest of India in terms of significant adoption of GM cotton. As the LMOs are most likely to be introduced in the form of seed, this ex ante SE assessment focused on the possible LMO introduction via seeds in castor and ground nut crops in Gujarat.

There are a number of traits that are being researched upon in India and elsewhere in a variety of commercial crops, food grains, vegetables and fruits. Some of these are: delayed ripening, insect resistance, fungal resistance, viral resistance, bacterial resistance, nematode tolerance, herbicide tolerance, drought tolerance, salt tolerance, other abiotic stress tolerance, nitrogen use efficiency, MS/FR (Male Sterility/Fertility Restoration), micronutrient enhancement, macronutrient enhancement, modified fatty acid, modified amino acid, and modified color.

The chosen traits for the study are salinity resistance and drought tolerance. We paired castor and salinity resistance and groundnut and drought tolerance for the following reasons.

As India in general and Gujarat in particular experience inadequate rainfall and droughts are becoming frequent. Already the Census of India, 2011 pointed out farmers leaving agriculture. Due to the increasing urbanization and industrialization in India, many farmers are selling away their land to pursue a different livelihood option. However, farmers who are dependent on agriculture have to have a coping strategy to face droughts and sustain themselves by engaging in cultivation. Hence, for such farmers' drought tolerant varieties are very useful. Gujarat has a long coastal line and coastal areas increasingly suffer from the salinity ingress[1] as shown in the bar chart below which makes it difficult for the farmers in such areas to continue with cultivation (Maliya, Lakhpat are in Kutch). In the desert region the salinity ingress is faster and higher. Further the inadequate rainfall also pushes the sweet table downwards which increases the salinity ingress. Hence, technologies are required to introduce such varieties that will grow even in areas affected by salinity ingress (Fig. 7.1).

7.1.1 Importance of Castor and Ground Nut Crops to Gujarat

Castor Ricinuscommunis L. is an important non-edible oilseed crop and is grown especially in arid and semi arid region. It is originated in the tropical belt of both India and Africa. It is cultivated in different countries on commercial scale. India, China and Brazil are the three major castor growing countries accounting for 90% of the world's production. Gujarat has a share (75%) in domestic production, followed by Rajasthan and Andhra Pradesh.

[1] The bar chart on salinity ingress has been sourced from http://iced.cag.gov.in/wp-content/uploads/2014/02/3.-PA-of-Salinity-Ingress-Prev.-Prog.-Gujarat.pdf.

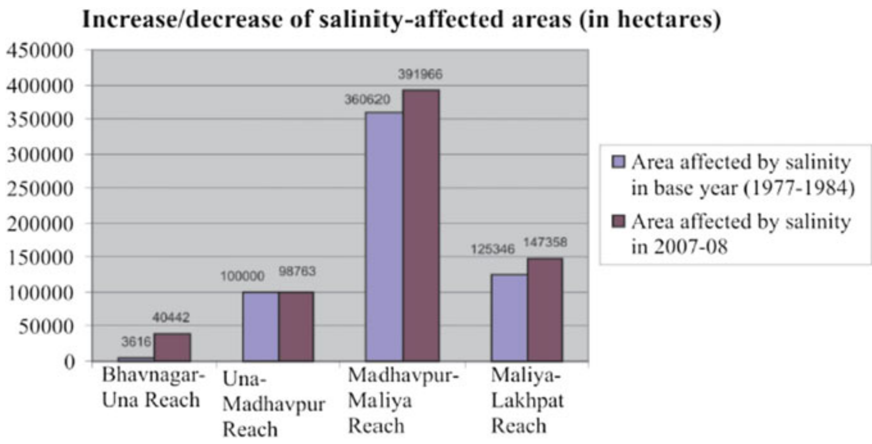

Fig. 7.1 Increase/decrease of salinity-affected areas in Gujarat. *Source* Data complied from reports of groundwater studies conducted by the Groundwater Division, Rajkot and the Gujarat Water Resources Development Corporation, Gandhinagar

Gujarat cultivates groundnut[2] in about 2 million ha with an annual production of 4.5 million tones and productivity of 2235 kg/ha. Inadequate availability of quality seeds of high-yielding varieties, terminal drought due to early cessation of monsoon and susceptibility to stem and collar rot are the major constraints limiting the productivity gains of groundnut in the state.

Both these products enjoy a relatively higher export advantage compared to other agri commodities from Gujarat.[3] While castor oil and the oil cake of castor are main products of castor and has a wide variety of uses from medicines, cosmetics to fuel, ground nut is an edible crop and used as a raw product, for making oil and oil cake for feed to the animals. Because of their wide range of uses and potential employment from production to value addition stages, these two crops are ideal candidates for the SEC.

7.1.2 Focus and Objectives of the Study

The major focus of this study is twofold: First is to look at the existing production practices adopted by the farmers; The second aspect has a GMO perspective. Here the focus is to assess the farmers' knowledge about GMOs, list down the possible pros and cons that could arise from the possible adoption of LMOs by the farmers and suggest the policy implication of the LMO adoption.

[2]http://www.icar.org.in/files/state-specific/chapter/47.htm, accessed on March 21, 2016.

[3]http://www.iimahd.ernet.in/publications/data/2002-09-05RavindraHDholakia.pdf.

In the following paragraph, the major objectives of the study and the indicators used to measure the same are listed:

The major objectives of the study are to understand the

1. Social profile of farmers (age, literacy, household size, irrigation assets)
2. Economic status (size of land holding, livelihood options pursued, farm assets, indebtedness, farm income)
3. Cost of cultivating the two crops (including costs incurred for material and labor inputs, transportation, etc.)
4. Constraints faced in cultivation and farm practices adopted to address (responses of farmers based on their experience)
5. Plant protection methods adopted in practice and their health impact
6. Farmers' perception about the chosen traits and the extent of production loss likely to be suffered by them
7. Risk perception of farmers and the possible ways of addressing the risks (points 5, 6 and 7 would be discussed based on the responses of farmers' experience).

7.1.3 Data and Methodology

The required data for the analysis were collected from farmers interviewing them with a structured questionnaire. The required information was collected for the reference year 2014–15. The choice of districts was made according to the data we obtained from Government of Gujarat. As per the data from 2007–08 to 2012–13 for the area under castor, Banaskantha and Kutch rank 1st and 2nd consistently and in 2012–13, these two districts had 12.83 lakh and 11.45 lakh hectares under castor. Using the same logic, we selected Junagadh and Jamnagar districts which had 38.7 and 39.7 lakh hectares under groundnut cultivation in 2009–10. As Gujarat frequently faces drought situations due to delayed and insufficient rains, we concentrated on studying the drought tolerant trait with ground nut producers and the salinity resistance trait with castor producers. We randomly chose five talukas and five villages in these two districts. In the village, after talking to the village sarpanch a list containing at least 40–50 castor and ground nut farmers was made in each village. This list consisted of farmers with both large and small land holdings. From this list, we randomly selected 20 farmers in each of the villages. Thus the sample consists of 101 castor farmers and 102 ground nut farmers (Table 7.1). There were no female farmers in our sample.

Methodology

The study uses descriptive statistics such as percentages and cross tabulations, to analyse the data collected from the field. Linear regression has been used to identify the determinants of the crop income for all the farmers. T test has been used to show the difference between the means for income and expenditure of two sets of farmers. Benefit cost ratios have been calculated using the income and paid out costs.

Table 7.1 Location of the farmers selected for the study

Crop	Name of the district and taluka	Name of the village	Total number of sample
Castor	*Kutch*		
	Rapar	Ramvav	21
	Bhachau	Bharudia	20
	Banashkantha		
	Deesa	Pamaru	20
	Palanpur	Gadh	20
	Vadgam	Thalvada	20
Groundnut	*Junagadh*		
	Visavadar	Khambha (gir) and Haripura	42
	Keshod	Shergadh	20
	Jamnagar		
	Jamnagar	Chavda and Suryapura	40
	Total number of farmers		203

Source Farmer survey 2015–16
Note Unless specifically stated, all the tables presented in this chapter have been compiled from the information collected from the farmer survey conducted during July–August, 2015 in Gujarat

Alternate benefit cost scenarios have been constructed allowing increases in the price and yield to discuss the adoption of trait related seeds by the farmers.

Limitations of the Study

In order to calculate the cost of cultivation, this study has considered only the hired labor charges and has not imputed wages for the family labor. Therefore, cost of cultivation here includes only the paid out costs like seeds, pesticides fertilizer, electricity, and wages paid to the hired labor.

The chapter is organized as follows. Section 7.2, following this introduction discusses the socioeconomic profile of the farmers; Sect. 7.3 analyses the labor use in cultivation; Sect. 7.4 provides the cost of cultivation of the two crops; Details of seed adoption and benefit cost scenarios are discussed in Sect. 7.5; Constraints faced in cultivation are provided in Sect. 7.6; Sect. 7.7 discusses the health issues due to pesticides; Sects. 7.8 and 7.9 provide a discussion on farmers knowledge about GM crops and their perception on risks associated with GM crops. Sections 7.10 and 7.11 give the conclusion and policy implications.

7.2 Socioeconomic Profile of the Chosen Farmers

The average age of the castor, ground nut and all farmers are 44, 46 and 45 years. Less than 10% of the farmers in our sample are above 60 years of age. 12, 11, and 11.3 percentage of farmers are in the age group of 21–30 compared to more than 25, and 30% of farmers in the 31–40 and 41–50 age group. The relatively less percentage of farmers in this age group perhaps indicates the less involvement of younger generation in agriculture.

Only 12.3% of the total farmers do not have formal school education and their number is relatively more among the castor growers. A sizeable percentage of the farmers have primary (45.8%) and high school education in the total sample (31.5%). While 51% of the castor farmers have primary education, 45% of the ground nut farmers have high school education. Only 5% each of the total farmers have done higher secondary and graduation.

There were a total of 1170 household (HH) members with these 203 farmers. The average size of the farmer HH is 5.7 members. 39.3, 35.7 and 25 per cent of the HH members are male, female and children respectively. Of the 1170 household members, 653 members or 56% of the household are engaged in farming and the rest are engaged in some other activity. Of those engaged in farming, 57 and 43% are male and female respectively.

604 persons have their own farm. Out of this, 59% are male. On an average our respondent farmers said that working in their own farm engaged them for 243.4 person days. Male members were engaged for 250.8 person days and female members were engaged for 232.9 person days in their own farm.

In castor also, while overall 253.7 person days of labor was involved, male members were engaged for 263.5 days compared to 241 person days for females. As ground nut is a kharif crop it requires relatively less person days compared to castor, and thus a total of 233 person days have been spent in ground nut cultivation. Here again, females were engaged for 223 person days compared to 239 person days for males.

7.2.1 Land Details of the Farmers

Except for 1.5% of the total farmers who had less than 5 years of experience in agriculture, experience of other farmers ranged from 6 years to more than 50 years in farming.

Of the total 203 farmers chosen for the study, 55.7, 37.9, and 6.4 constitute the small, medium and large land holders respectively (Table 7.2). As is evident, the sample is tilted more toward small land holders in both castor and ground nut crop.

Agricultural income remains as the major source of income for farmers of different size groups. Around 8% of the total income comes from other activities. For all farmers, annual income per hectare is estimated at Rs. 58,414. The per hectare annual

Table 7.2 Distribution of chosen farmers by size of holdings, crop (%) and average annual income in Rs

	Small	Medium	Large	N
Castor	48.5 (74,977)	43.6 (54,536)	7.9 (26,424)	101
Groundnut	62.7 (85,673)	32.4 (66,287)	4.9 (37,364)	102
Total	55.7 (80,328)	37.9 (59,454)	6.4 (30,254)	202

Source Farmer survey 2015
Note Small, medium and large farmers are defined as those with <3 ha, 3.1–9.9 ha and >10 ha respectively. Figures in parentheses indicate the average annual income

earnings of the farmers with smaller size holdings is higher than that of earnings of farmers from medium and large size holdings in aggregate and for the two crops under consideration. This trend, while different from the usual could be because of the fact that (1) both small and medium farmers have reported income from other activities also, the share of which is relatively lower for the large farmers and (2) could also be due to under reporting of income by the large farmers.

Small- and medium-sized holders producing castor receive 12 and 11% of their income from other than agricultural activities, which is higher than the corresponding category producing ground nut.

7.2.2 Irrigation Status of Land Cultivated by Farmers

In all, the per capita land holding of sample farmers is 3.8 ha. Castor farmers had a relatively larger holding than the ground nut farmers at 4.3 ha. The percentage of leased in and uncultivable land to the total land is only 0.34 and 0.84, all the land reported is cultivable by the farmers (Table 7.3).

The chosen farmers are in an advantageous situation as 95% of the land is cultivated under irrigated conditions. Tube well irrigates 81% of the area and 17.6% by open wells.

Tubewell irrigation has become prime most source since 2000 and 78% of tubewell structures have come up after 2000. On an average, setting up a tube well structure is relatively costlier (at Rs. 3.61 lakh) compared to a well (Rs. 2.15 lakh) or a drip irrigation structure (Rs. 1.45 lakh).

44 per cent of the total 203 farmers own a tractor (Table 7.4). The number could be less since on an average, a tractor costs around Rs. 4.6 lakhs (table not shown here). Overall 60% of the farmers have farm sheds. 58% each of the castor and ground nut producers have farm sheds. Per structure cost of the farm shed for both the castor and the ground nut producer is about Rs. 74,000.

Table 7.3 Total cultivable land by status of irrigation

Crop	Total land in hectare (own+leased in)	Total irrigated land in hectare (own+leased in)	Total unirrigated land in hectare (own+leased in)	% of irrigated land	% of Rainfed land	Percapita land-holding in hectare
Castor	437.77	407	30.77	93.0	7.0	4.3
N	101	98	8			
Groundnut	325.43	319.11	6.32	98.1	1.9	3.2
N	102	100	6			
Total	763.2	726.11	37.09	95.1	4.9	3.8
N	203	198	14			

Source Farmer survey 2015

Table 7.4 Tractor ownership by crop

Crop	Number of tractors	% of tractor owners to total number of farmers
Castor	54	53.4
Groundnut	35	34.3
Total	89	43.8

Source Farmer survey 2015

7.2.3 Cropping Pattern

A sizeable percentage of land is under sandy (47.3), reddish (18.3) and black (22.4) soil. We also note that majority of the castor farmers cultivate castor in sandy, reddish and fertile soil, while ground nut is grown more in black soil, reddish, and fertile soil.

Cropping intensity of the total farmers is 177 (Table 7.5). For castor farmers cropping intensity is higher than the ground nut farmers and it is higher than the combined average. This is due to the fact that castor farming extends to rabi season also. Further due to the rain during the kharif season, the number of crops grown is also higher than the rabi and summer season (Table 7.6).

In kharif season a total of 737.9 ha have been used for cultivation. In rabi season, 324.5 ha of land or 44% of the land has been used for cultivation and in summer, only 14% or 102.6 ha has been put to use. Implicitly kharif season is more important for the farmers compared to rabi and summer season. In kharif season, castor and ground nut occupy almost same quantity of land followed by cotton and food grain. In rabi season, spices (cumin) and food grains (33.5) are the two important crops. In summer season, only a few farmers were able to continue with food grains and fodder.

Table 7.5 Cropping intensity by season

	Castor				Ground nut				For all farmer
	Kharif	Rabi	Summer	Total	Kharif	Rabi	Summer	Total	Total
Gross cropped area	422.7	386.6	81.5	890.8	315.2	129.0	21.1	465.24	1356
Net area sown	437.77	437.77	437.77	437.77	325.43	325.43	325.43	325.43	763.2
Cropping intensity	96.6	88.3	18.6	203.5	96.9	39.6	6.5	143.0	177

Source Farmer survey 2015

Table 7.6 Allocation of land for crops in different seasons

Kharif		Rabi		Summer	
	% of land under crops		% of land under crops		% of land under crops
Castor	25.9	Food grain	33.5	Groundnut	0.8
Groundnut	24.5	Vegetables	7.2	Food grain	56.7
Cotton	20.9	Pulses	2.1	Fodder	27.6
Food grain	13.6	Fodder	4.5	Spices	14.8
Vegetables	10.3	Tobacco	3.1	Total land in ha	102.6
Pulses	0.8	Spices	46.1		
Fodder	2.3	Isabgul	3.4		
Spices	1.6	Total land in ha	324.5		
Total land in ha	737.9				

Source Farmer survey 2015

7.2.4 Cropping Pattern and Farm Income

The following points emerge from the table on cropping pattern (Table 7.7):

1. In Kharif season yield per hectare of castor (23.2 qtl) is higher than any other crop
2. Yield of cotton is (17.4 qtl) is better than ground nut and food grain (15 qtl).
3. Though ground nut occupies more land (24.5%) than land under food grains (13.6%), yield level of both have been the same.
4. Price realization per hectare of castor is higher than ground nut and cotton.
5. Of the total production, except for food grain where only 33% has been offered for sale, more than 95% (castor, cotton, vegetables and pulses) and 90% (ground nut and spices) are sold to the market.
6. Fodder production is entirely for the consumption of livestock maintained at home.
7. Price realization of the marketed products (average price realized per quintal for marketed products), is very high for pulses, followed by cotton, ground nut, vegetables and castor.
8. In rabi season, yield of vegetables has been higher than any other crop. This is basically because of a few farmers cultivating potatoes. Hence the price realized per hectare is also the highest for vegetables compared to other crops. The next highly valued product is tobacco.
9. Farmers also seem to keep only food grain for their self-consumption and less vegetables and hence only 44% of food grains has been offered for sale.

Table 7.7 Cropping pattern and farm income of the farmers in Gujarat

Name of the crop	Kharif Season				Rabi Season					Summer season				
	Yield (qtl) per hectare	Production (qtl) sold per hectare	Gross income per hectare	Average price realized per quintal	Name of the crop	Yield (qtl) per hectare	Production (qtl) sold per hectare	Gross income per hectare	Average price realized per quintal	Name of the crop	Yield per hectare	Production (qtl) sold per hectare	Price realized per hectare	Average price realized per quintal
Castor	23.2 (4473)	22.3 (4316)	79,151	3548.5	Food grain	25.6	11.1	15217.1	1366	Groundnut	24.7	24.7	111111.1	4500
Groundnut	15.2 (2746)	13.8 (2501)	60,165	4018.5	Vegetables	261.6	261.3	203876.8	780.1	Food grain	25.8	9	11768.9	1309.2
Cotton	17.4	17.4	70,226	4039.2	Pulses	8.3	8	33096.3	4113	Fodder	3.5	1.4	1692.5	1200
Food grain	15.3	5.0	9985	1999.1	Fodder	0.1				Spices	7.6	7.5	49362.7	6590.4
Vegetables	9.4	9.1	34,405	3778.6	Tobaco	19.3	19.3	98984.3	5141					
Pulses	8.4	8.0	39,228	4880	Spices	12.1	11.7	72160.4	6175					
Fodder	0.9				Isabgul	3.7	3.7	21454.7	5863					
Spices	7.3	6.6	55,144	8370.5										

Note figures within parentheses provided for cotton and ground nut indicate the total production and total quantity sold respectively
Source Farmer survey 2015

Table 7.8 Production trends in castor and ground nut cultivation during 2012–2015

	Castor			Groundnut		
	Production in quintal	Land in hectare	Yield qtl per hectare	Production in quintal	Land in hectare	Yield qtl per hectare
2012–13	4276	186.12	23.0	1955	166.4	11.7
2013–14	4420	198.84	22.2	2207	158.14	14.0
2014–15	4473	191.09	23.2	2746	180.62	15.2

Source Farmer survey 2015

10. A small quantity of pulses and spices are also retained perhaps for home consumption.
11. Tobacco and isabgol are produced for the market only.
12. In terms of average price realized per quintal for marketed product, spices and isabgol occupy the top two slots followed by tobacco and pulses.
13. In summer, cultivation is limited to food grain, spices, fodder and ground nut.
14. If we consider ground nut yield of summer season as an exception, spices cultivation has yielded more than fodder which has occupied 27.6% of land.
15. Food grain production continues to be mainly for home consumption.
16. Price realization per quintal of spices is higher than the rest of the products.

Castor occupies relatively more land and the yield per hectare is also higher than ground nut. But percentage increase in production from 2012 to 2015 of ground nut at 30% is higher than that of castor at 1.73% (Table 7.8).

7.2.5 Indebtedness

According to GOI (2015)[4] 42.6% of the agricultural households are indebted and the all India average is 51.9. 68% of the sample farmers reported to be being in debt, which is higher than the state and the all India average of which 60 and 75.5% cultivate castor and groundnut respectively.

Farmers have availed loans to meet capital expenditures like purchase of tractors, installing pipelines or sprinklers or for meeting recurring farming expenditures like seeds, fertilizers or paying hired laborers. We note that loan for buying seeds has been the prime most reason for all farmers and for castor and ground nut cultivators followed by purchase of pesticides and fertilizers. Castor cultivators also reported to have availed loan to incur capital investments like purchasing tractors (11%), laying pipeline (1.6%), sprinklers (1.6%) and tube well (4.7%) compared to the ground nut farmers.

[4] Agricultural statistics at a glance 2014.

Except for one farmer (1%) who had taken loan from informal sources for buying tractors, the rest have sought loan from formal sources like commercial banks and cooperatives. For 70 and 80% of the castor and ground nut cultivators, cooperatives have been the major loan provider.

The rate of interest of loans as reported by the farmers ranged from 1.5 to 13% per annum. 66 and 18 per cent of all farmers reported to have availed loan at the rate of interest of 7 and 8% respectively from commercial banks and cooperative banks. 62, 20 per cent and 69 and 15 per cent of the castor and ground nut cultivators also reported to have availed loan at 7 and 8% respectively.

7.3 Labor Use in Castor and Ground Nut Cultivation

7.3.1 Use of Family and Hired Labor in Different Farm Operations

Both the crops under consideration have potential for employment. A total of 28,924 person days have been used in cultivation by the chosen farmers. Of this 47% has been contributed by the family labor. Females constitute 33% of the total labor force. Hired labor constitutes 25% of the total labor force. Castor cultivation, accounts for a total of 14,989 person days (or 52% of the total) in different farming operations. Family labor constitutes 49% of the total labor. 33% is the female labor force in the total labor and 24% is the hired female labor in the total labor involved in different operations. Ground nut cultivation involved 13,935 person days in total. The constituents of the labor days are 45% family labor, 32% female labor and hired female labor 25%.

At aggregate level and in the two reference crops involvement of family labor is higher in land preparation, irrigation management, fertilizer application, and in pesticide application.

In weeding and harvesting of castor, female labor force constitutes 51 and 46% of the total labor. It follows that hired female labor is involved to the extent of 43 and 34% in cultivation (Table 7.9).

7.4 Cost of Cultivation

In this section, we first provide the cost of material inputs and then present the total cost (paid out costs) of cultivation consisting of hired labor charges and material charges. The subsection discusses the determinants of crop income (Table 7.10).

Table 7.9 Details of labor days by crop

Farm operations	Labor details for all farmers				Labor details for castor farmers				Labor details for ground nut farmers			
	% of family labor to total labor	% of female labor to total labor	% of hired female to total labor	Total labor days involved family + hired	% of family labor to total labor	% of female labor to total labor	% of hired female to total labor	Total labor days involved family + hired	% of family labor to total labor	% of female labor to total labor	% of hired female to total labor	Total labor days involved family + hired
Land preparation	67	13	2	759	65	13	2	352	68	13	2	407
Sowing	52	18	8	885	54	21	9	408	49	16	7	477
Irrigation	97	0	0	5090	96	0	0	3106	99	0	0	1984
Weeding	21	51	43	9282	23	51	42	3887	20	51	43	5395
FYM, organic/bio-fertilizers	27	32	22	732	27	30	20	410	26	34	25	322
Urea (N)	97	22	0	543	97	24	1	385	94	18	0	158
DAP	93	14	1	409	95	16	2	177	92	13	0	232
Phosphorus (P)	100	21	0	14	100	33	0	6	100	13	0	8
Potash (K)	88	29	0	34	100	0	0	2	88	31	0	32
Other fertilizer1	97	13	0	39	94	6	0	17	100	18	0	22
Weedicide	85	0	0	512	77	0	0	155	88	0	0	357
Insecticide	87	0	0	806	87	0	0	163	87	0	0	643
Pesticide	88	0	0	649	93	0	0	136	87	0	0	513
Harvesting	30	46	34	8256	33	46	33	5289	26	46	36	2967
Post harvest field operations	44	24	9	744	41	30	15	328	46	19	4	416
Bagging	46	24	11	157	46	25	12	155	100	0	0	2

(continued)

Table 7.9 (continued)

Farm operations	Labor details for all farmers				Labor details for castor farmers				Labor details for ground nut farmers			
	% of family labor to total labor	% of female labor to total labor	% of hired female to total labor	Total labor days involved family + hired	% of family labor to total labor	% of female labor to total labor	% of hired female to total labor	Total labor days involved family + hired	% of family labor to total labor	% of female labor to total labor	% of hired female to total labor	Total labor days involved family + hired
Transportation	31	0	0	13	31	0	0	13				
Total	47	33	25	28,924	49	33	24	14,989	45	32	25	13,935

Source Farmer survey 2015

Table 7.10 Cost of fertilizer inputs (Rs)

Farm operations	Castor			Ground nut			Aggregate		
	Cost of materials	Total quantity in kilo	Total quantity/hectare	Cost of materials	Total quantity in kilo	Total quantity/hectare	Cost of materials	Total quantity in kilo	Total quantity/hectare
Urea (N)	371,800	53,850	265.7	10,1505	15,300	156.6	47,3305	69,150	230.2
DAP	591,820	21,250	110.3	505,058	22,925	141.4	1,096,878	4,4175	124.5
Phosphorus (P)	3200	170	33.4	11,600	395	55.4	14,800	565	46.2
Potash (K)	300	10	5.0	21,586	1680	119.9	21,886	1690	105.4
Other fertilizer1	18,590	864	101.6	19,390	1019	89.9	37,980	1883	94.9
Other fertilizer2	8650	75	10.8	3000	200	61.7	11,650	275	27.0
Per hectare use	4886.29		374.5	6312.097		395.8	5373.01		381.9

Source Farmer survey 2015

7.4.1 Cost of Material Inputs

In aggregate, all the farmers have used an average of 381.9 kg of fertilizers per hectare incurring an average expenditure of Rs. 5373.01 per hectare. Castor cultivators have used 374.5 kilos of fertilizers per hectare spending Rs. 4886.29 per hectare. Ground nut cultivators have spent Rs. 6312.1 per hectare to buy 395.8 kilos of fertilizer per hectare.

The difference between the castor and the ground nut farmers is evident in the use of phosphorus and potash which is higher in the case of ground nut farmers, that is explained by the relatively small number of farmers while the urea and DAP use is more in the case of castor users.

A total of 1291 trolleys of farm yard manure has also been used in addition to this at a total cost of Rs. 1,054,950. If we include this cost, then the per hectare cost of all fertilizer is Rs. 8794.8.

The normal seed rate of sowing for castor and ground nut is 5 kg/ha and 100 kg/ha respectively (Table 7.11). Our sample farmers have used 4.7 kg and 120.3 of castor and ground nut per hectare respectively. In all both castor and ground nut farmers together have spent Rs. 1,331,350 on purchasing seeds. While castor farmers have incurred a seed cost of Rs. 1363 per hectare, ground nut farmers have incurred a seed cost of Rs. 10,052 per hectare.

Castor farmers are dependent on the market for their seed inputs while the ground nut farmers use some farm saved seeds.

A total of 449 kilos of pesticide or 1.8 kilos per hectare has been used for which farmers have spent totally Rs. 216,220 or a per hectare cost of Rs. 859.3 (Table 7.12). Here again we observe that though castor farmers have used 2.9 kg of pesticides per

Table 7.11 Seed use in cultivation

Crop	Total land in hectare	Seed quantity in kg	Seed cost (Rs.)	Per hectare cost	Per hectare use of seed in kg
Castor	203.5	947	277,250	1363	4.7
Groundnut	104.9	12,615	1,054,100	10,052	120.3
Total	308.3	13,562	1,331,350	4318	44.0

Source Farmer survey 2015

Table 7.12 Pesticide use in cultivation. We have used a conversion rate of 1 l = 0.93 kg

	Pesticide use in kg	Pesticide expenditure	kg per hectare	Exp Rs per hectare
Castor	256.2	40,580	2.9	454.2
Groundnut	193.1	175,640	1.2	1082.4
Aggregate	449.3	216,220	1.8	859.3

Source Farmer survey 2015

hectare, the cost per hectare is 454.2 which is 53% of the aggregate expenditure on pesticides.

7.4.2 Total Cost of Cultivation

The following points emerge from Table 7.13 and Fig. 7.2:

1. Farmers have incurred a total cost (paid out cost) of Rs. 52,657 per hectare at aggregate level. The per hectare cost of producing ground nut and castor amount to Rs. 56833.5 and Rs. 46615.4 respectively.
2. Over all, share of fertilizer cost is the highest for both castor (26%) and ground nut farmers (28%). The next higher cost for castor farmers is electricity bill (26.9) and weeding cost (17.2%) for the ground nut farmers compared to other costs.
3. The higher cost of electricity bill for the castor farmers is explained by the relatively higher number of times (1047 times totally) of irrigating their castor field during the entire season compared to 332 times of watering by the ground nut farmers. Thus, while castor farmers have irrigated 10.6 times per farmer during the total season, ground nut farmers have irrigated only 3.32 times per farmer during the course of ground nut cultivation.
4. At the aggregate level and for the individual crops, cost of hiring machines for land preparation is higher than the cost of machinery reported for other operations.
5. Material input costs are higher in the case of sowing, fertilizer and pesticide spraying.
6. In weeding and harvesting, the per hectare cost comprises mainly of the labor costs.
7. Cost of electricity for irrigation is substantial in the total cost per hectare, mainly due to the high tariff structure prevailing in Gujarat.

7.4.3 Determinants of Crop Income

In order to understand the determinants of crop income of farmers, a number of indicators were first listed to see if they were correlated with crop income. Based on the well established relationship between farm income and a few indicators, like irrigation, use of F1 seeds, farm machinery like tractor and fertilizer use are expected to have a positive and significant relationship with economic returns on the crop. Similarly, higher labor cost, quantity of pesticide use or number of chemical sprays per hectare are expected to have a negative impact on the economic returns to the farmers. Based on the correlation, a few important variables influencing crop income were chosen (Appendix Table 7.30 gives the cross-correlation matrix). These are: use of F1 seeds indicated by the use of seeds bought from seed shops. A value of 1 and 0 has been used to denote when the seeds have been bought from the shop

Table 7.13 Details of paid out costs incurred during various farming operations

Farm operations	Castor (percentage share of costs)						Ground nut (percentage share of costs)					
	Hired Bullock cost (Rs)	Hired Machine cost (Rs)	Labor cost	Cost of materi-als	Transportation cost	Total cost per hectare Rs.	Hired Bullock cost (Rs)	Hired Machine cost (Rs)	Labor cost	Material cost	Transportation cost	Total cost per hectare (Rs)
Land preparation		90.9	9.1			2577.9		92.0	8.0			3333.8
Sowing		19.1	10.2	70.7		1928.0	1.4	6.3	4.6	87.7		7248.0
Irrigation			100.0			1545.5			100.0			1207.9
Weeding	0.66	13.1	86.3			3627.3	1.9	2.5	95.6			5930.2
FYM, organic/bio-fertilizers		11.4	17.0	71.6		3101.7		5.0	6.2	88.8		5817.2
Urea (N)			0.6	99.4		1845.9			2.2	97.8		1062.2
DAP			0.4	99.6		3104.5			0.8	99.2		3205.5
Phosphorus (P)				100		628.7				100.0		1626.9
Potash (K)				100		148.5			4.0	96.0		1605.0
Other fertilizer1				100		2187.1				100.0		1709.9
Other fertilizer2				100		1246.4				100.0		925.9
Weedicide			5.8	90.1		905.5			6.6	93.4		1658.2

(continued)

Table 7.13 (continued)

Farm operations	Castor (percentage share of costs)						Ground nut (percentage share of costs)					
	Hired Bullock cost (Rs)	Hired Machine cost (Rs)	Labor cost	Cost of materi-als	Transportation cost	Total cost per hectare Rs.	Hired Bullock cost (Rs)	Hired Machine cost (Rs)	Labor cost	Material cost	Transportation cost	Total cost per hectare (Rs)
Insecticide			9.9	88.9		505.2			6.3	93.7		2232.9
Pesticide			5.7	92.5		475.4			9.4	90.6		1194.2
Harvesting			100.0			3850.4		3.4	96.6			3039.1
Post harvesting costs		2.5	89.5		8.0	339.9			94.1		5.9	512.6
Bagging, cost		5.6	38.0		56.4	577.1					100	664.8
Transportation cost		13.6	28.5		57.9	364.1			100.0			123.0
marketing cost			100.0									114.5
Others (Thresher)		96.4	3.6			1128.9		100.0				1366.8
Weed control in summer		95.5	4.5			3981.4		94.4	5.6	0	0	3867.1
Electric bill for irrigation				100		12546.0				100	0	8388.0
Total cost						46615.4						56833.55

(continued)

Table 7.13 (continued)

Farm operations	Aggregate (percentage share of costs)					
	Hired Bullock cost (Rs)	Hired Machine cost (Rs)	Labor cost	Material cost	Transportation cost	Total cost per hectare (Rs)
Land preparation		91.6	8.4			2954.2
Sowing	1.1	9.5	5.9	83.5		4317.0
Irrigation			100.0			1470.1
Weeding	1.4	7.0	91.6			4661.9
FYM, organic/bio-fertilizers		7.2	9.8	83.0		4495.1
Urea (N)			1.0	99.0		1590.9
DAP			0.6	99.4		3150.4
Phosphorus (P)				100.0		1211.1
Potash (K)			3.9	96.1		1421.5
Other fertilizer1				100.0		1914.3
Other fertilizer2				100.0		1144.4
Weedicide			6.2	92.0		1230.3
Insecticide			6.9	92.9		1456.3
Pesticide			8.7	91.0		933.6
Harvesting		1.4	98.6			3480.6
Post harvesting costs		1.1	92.0		6.9	414.4

(continued)

Table 7.13 (continued)

Farm operations	Aggregate (percentage share of costs)					
	Hired Bullock cost (Rs)	Hired Machine cost (Rs)	Labor cost	Material cost	Transportation cost	Total cost per hectare (Rs)
Bagging, cost		3.6	24.8		71.5	604.8
Transportation cost		11.2	40.8		47.9	272.0
marketing cost			100.0			114.5
Others (Thresher)		98.3	1.7			1243.2
Weed control in summer		94.8	5.2			3915.7
Electric bill for irrigation				100		10661.0
Total cost						52657.4

Source Farmer survey 2015

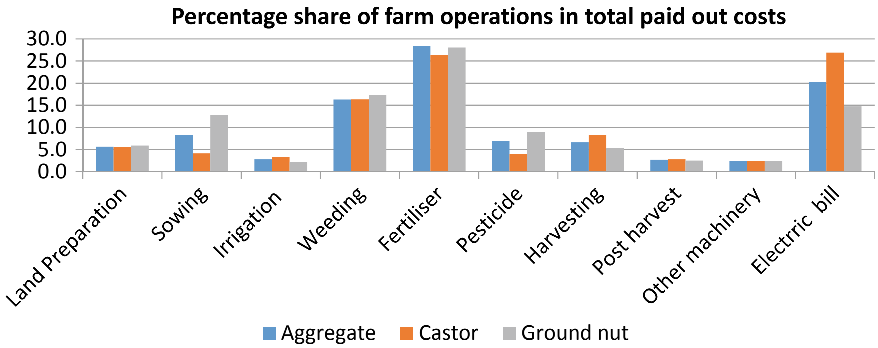

Fig. 7.2 Percentage share of farm operations in total paid out costs. *Source* Farmer survey 2015

or otherwise, respectively. Chemical sprays per hectare is the total of all chemical sprays (sprays used to control pests and weeds) used in cultivation. Electricity charges paid per hectare has been used as a proxy for irrigation costs. The charge for hiring machinery during land preparation was reported by most farmers. Deep ploughing using the tractors helps to revitalize the land and increases the land productivity. Hence, we have used the dummy value of 1 for ownership of tractors and 0 otherwise.

A simple regression exercise was carried (Table 7.14) with dependent variable as log value of crop income per hectare. The model explains an R square of 0.203, which is fairly acceptable for a cross sectional data consisting of a relatively small sample of 203 farmers and the results are only indicative. The overall model has the Durbin–Watson statistic at 1.792, indicating that the chosen variables do not have auto correlation between them. The results are on the expected lines for all the variables, except the chemical sprays per hectare.

Table 7.14 Determinants of crop income per hectare

Dependent variable log value of crop income per hectare	
Independent variables	Coefficients
Constant	10.755(0.107)***
Seed bought (yes 1, 0 otherwise)	0.398(0.109)***
Cost of irrigation per hectare	.00000389(0.000)**
Chemical sprays per hectare	0.001(0.01)
Seed quantity used per hectare	- .003(.001)***
R Square	0.203
F	12.609***
Durbin Watson	1.792

*Note**, **, *** denote the significance at 1, 5 and 10 per cent respectively
Source Farmer survey 2015

Table 7.15 Gross and Net income (Rs) per hectare realized by farmers

Crop	Gross Crop income per hectare	Paid out costs per hectare	Net income per hectare	**Benefit/cost ratio**	Av. price per quintal	Land/ha
Castor	79,151	46615	32,535	**1.697**	3548.47	191.09
Ground nut	60165	56833	3331	**1.058**	4019	180.64

Source Farmer survey 2015
Note Gross income for the castor and ground nut cultivators have been derived from Table 7.13. As both the crops are cultivated in Kharif season, we have considered the income from sale of kharif crops only

Seed quantity used per hectare is negatively associated with crop income, indicating perhaps, the excess use of seeds. Particularly in the case of groundnut seeds, a higher level of seed use per hectare (120 kg) than the recommended quantity of 100 per hectare is practiced by the farmers. Hence a higher cost spent on seeds would reflect on the net income. Variable, seed bought from the market is positive and significant indicating that majority of farmers used F1 seeds expecting an increase in the yield and thereby farm income, as against the farm saved seeds, where the yield could be relatively lower. Irrigation is important for better yield which is reflected in the positive and highly significant result but its influence on crop income, is small.

We expected that the number of chemical sprays per hectare would increase the cost and thereby a negative association with crop income. However, the positive and weak significance perhaps show that since pest and disease has been reported as a major constraint by majority of farmers, and therefore controlling the same would result in better income (Table 7.15).

The mean difference between the gross income of both the farmers is positive and significant at 5% level (t8.68, 0.002). But the difference between the paid out costs between the two sets of farmers is negative and statistically significant at 10% level (−1.781, 0.076).

7.4.4 Benefit Cost Scenario of Castor and Ground Nut Farmers

In this section, we have attempted to construct different benefit cost scenario levels for both castor and ground nut farmers with an assumption that the seeds with newer traits are available for both the cultivators. 15 different scenarios have been constructed based on the present levels of benefits that are presented in Table 7.16. In doing this, we have assumed that only the price of the seed to change by 10, 25 and 50% more than the prevailing price and everything else is constant. In the next step, the yield level is assumed to change at 5, 10, 15 and 20% level along with the increase in price of the seeds at 10, 25, and 50% level.

Table 7.16 Benefit cost scenario for castor and ground nut farmers

		Castor		Groundnut	
		Net income Rs/ha	BCR	Net income Rs/ha	BCR
Present scenario	Benefit at the present level of seed cost	32,536	1.698	3332	1.059
Scenario 1	With 10% increased seed cost	31,036	1.645	−7725	0.886
Scenario 2	With 25% increased seed cost	30,832	1.638	−9233	0.867
Scenario 3	With 50% increased seed cost	30,491	1.627	−11,746	0.837
Scenario 4	With 5% increase in yield with 10% increase seed cost	39,071	1.812	−3748	0.945
Scenario 5	With 5% increase in yield with 25% increase seed cost	38,867	1.804	−5255	0.924
Scenario 6	With 5% increase in yield with 50% increase seed cost	38,526	1.792	−7768	0.892
Scenario 7	With 10% increase in yield with 10% increase in seed cost	43,223	1.898	−693	0.990
Scenario 8	With 10% increase in yield with 25% increase seed cost	43,019	1.890	−2201	0.968
Scenario 9	With 10% increase in yield with 50% increase seed cost	42,678	1.877	−4714	0.934

(continued)

Table 7.16 (continued)

		Castor		Groundnut	
		Net income Rs/ha	BCR	Net income Rs/ha	BCR
Scenario 10	With 15% increase in yield with 10% increase in seed cost	47,375	1.985	2361	1.035
Scenario 11	with 15% increase in yield with 25% increase in seed cost	47,170	1.976	854	1.012
Scenario 12	With 15% increase in yield with 50% increase in seed cost	46,829	1.962	−1659	0.977
Scenario 13	With 20% increase in yield with 10% increase in seed cost	51,526	2.071	5416	1.080
Scenario 14	With 20% increase in yield with 25% increase seed cost	51,322	2.062	3908	1.056
Scenario 15	With 20% increase in yield with 50% increase seed cost	50,981	2.048	1395	1.019

Source Calculated by the author

We notice that for the castor and the ground nut farmers, the initial benefit cost ratio stands at 1.698 and 1.058 respectively, indicating that the castor farmers benefit more from castor cultivation than the ground nut farmers.

Scenario 1 to 3: When the price of the seeds is increased by 10, 25 and 50% more than the present level, BCR of both the farmers declines. However, while for the castor farmers the BCR is still more than 1.6 (because of the initial relatively better level of BCR for castor farmers), ground nut farmers' BCR reduces below 1, indicating that the benefits of ground nut cultivation declines when the price of the seed input increases.

Scenario 4 to 6: Here the BCR is constructed when yield for castor and ground nut farmers increases at 5% level, and the price of the seeds increases by 10, 25 and 50%. Here again, the BCR of the castor farmers improves to 1.812 at the first instance, but drops to 1.792 when the price of the seeds increases by 50%. However, even at this level, the BCR is equivalent to the BCR that the castor farmers started with.

For the ground nut farmers, the BCR improves to 0.945 with 5% increase in the yield and 10% increase in the seed price. However, the subsequent increase in the price of the seed reduces the BCR for ground nut farmers.

Scenario 7 to 9: When the yield increases by 10%, castor farmers are much better off with their BCR improving to 1.898 and reducing to 1.877, with 50% increase in seed price. But the BCR of the ground nut farmers continue to be below 1 as with 10% increase in yield and price increase, their BCR has improved from 0.892 to 0.990. With 50% increase in cost of seeds, increase in 10% yield is not sufficient to improve the BCR to 1 or more than 1.

Scenario 10 to 12: Increase in yield level by 15% obviously improves the BCR of the castor farmers much higher than the earlier levels. With 15% yield increase, the ground nut farmers are also able to cover their entire paid out costs, up to the level of 25% increase in seed cost. Yield increase of 15% is not sufficient to improve the BCR to 1 or above 1, when the seed price increases by 50%.

Scenario 12 to 15: At 20% increase in yield level, the BCR of the castor farmers increases to more than 2 and even with a 50% increase in seed cost, the BCR reduces only to 2.048. For ground nut farmers, while the increase in yield level by 20% more than the initial benefit scenario, improves the BCR to more than 1 at three different seed price scenario. However, the BCR (1.080 and 1.056) is equal to or higher than the initial BCR 1.058 only up to the price increase level of 25%. With 20% yield increase and 50% price increase, the BCR for ground nut farmers reduces to 1.019 which is below the initial BCR of 1.058.

Hence, it is inferred from this analysis that for ground nut farmers in Gujarat, an increase in yield level of at least up to 20% is essential, if the seeds with the newer trait for drought tolerance are offered at 25% more than the prevailing price level. With the 20% increase in the yield the farmers will not be worse off than their initial level of benefits. For the castor farmers in Gujarat, perhaps because of the higher yield level, the subsequent increase in the yield and price of the seeds do not make them worse off than their starting level of benefits.

However, the triennium average of crop pattern over the period 1970–73 to 2005–08 by Pathak and Shah (2010, p. 17) point out a decline in the area under groundnut from 22.07 (area as per cent to gross cropped area) in 1970–73 to 17.77 (2005–08). During the same period, area under castor increased from 0.67 to 3.72, indicating the shift away from ground nut. These authors also note the higher variability in yield rates in ground nut 37.83 (CVin %) (2001–02 to 2008–09). During the same period variability in the yield of castor was 13.42 (CVin %) (p. 21). Nevertheless, to sustain the interest of farmers in continuing with ground nut, yield levels should increase substantially and also the variable costs incurred by the farmers should be contained by appropriate farm management practices.

7.5 Details of Seed for the Reference Crop

Following are the interesting information on the seeds purchase provided by farmers

- 100 per cent of the castor seeds are bought from market
- 38% of ground nut farmers used farm saved seeds for cultivation
- Castor seeds are bought mainly from agro shops, seed corporation and universities
- 34% of ground nut seeds come from oil mills
- 75 per cent of castor and ground nut farmers buy seeds from the shops in taluka head quarters
- 70–80 per cent of both castor and ground nut cultivators had to travel around 10–40 km to buy seeds
- 99 per cent of the farmers decide the seed variety to be used by themselves
- 85 per cent of the farmers reported germination quality of more than 75%
- More than 70% of the farmers have selected their seeds for better production
- Three best features of the chosen castor seeds as reported by farmers are: better production (32), more branches (15)and no drying of the plant (16)
- In ground nut –better production (37), bigger nuts (22) and less falling off the leaves were the features reported by farmer
- Both farmers said that the chosen varieties are not resistant to pests and farmers were not aware of any variety that is resistant to pests available in the market
- 80% farmers of both the crops said that the seller neither gives technical advice to select the seeds nor forces the farmers to buy a particular seed
- More than 95% of the farmers have bought the variety paying cash
- 64 and 80 per cent of the castor and ground nut farmers have been buying seeds from the same shop for less than five years
- Majority of the castor farmers reported buying pesticides and fertilizer from the same shop
- An average of Rs. 290 and 84 have been paid to buy a kilo of castor and ground nut seeds respectively (Fig. 7.3).

An average of Rs. 293 and Rs. 84 has been paid by farmers to buy a kilo of castor and ground nut seed (Table 7.17).

Concentration of farmers reporting adoption of new seed variety is observed in the years 2008, 2010, 2012 and 2013 in the case of castor. Ground nut farmers seem to have adopted the said varieties in 2005, 2008, 2010 and 2012.

In the context of Bt adoption in Gujarat, it was observed that farmers experiment new varieties first in a very small portion of land and then commit larger areas, if they are satisfied with the yield and other features of the seed variety (Lalitha and Viswanathan 2015). Similarly in the case of castor 16, 10 and 13% of farmers reported experimenting their first variety only with 0.5, 0.9 and 1.2 ha of land respectively. In the case of ground nut 29 and 25% of farmers committed only 0.8 and 1.6 ha of land for the new variety.

Reasonable price (42.4) and good quality (29.6) are the two major reasons for the farmers to select their present seed source. Apart from their present source,

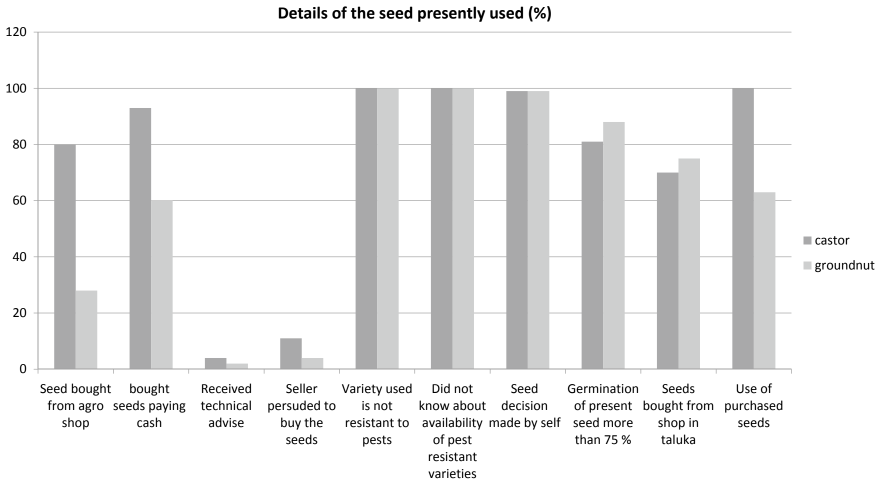

Fig. 7.3 Details of the seed presently used (%). *Source* Farmer survey 2015

Table 7.17 Price per kilo and quantity of seed bought

Crop	Seed quantity in kilo	Seed cost (Rs.)	Average price per kilo Rs.
Castor	947	277,250	293
N	101	101	
Groundnut	12,615	1,054,100	84
N	64	64	
Total	13,562	1,331,350	98
N	165	165	

Source Farmer survey 2015

farmers are also aware of seed sources like cooperative societies/seed corporation, krishivigyan Kendra and Krishi universities. However, cooperative societies and seed corporations are more popular with the farmers than other sources (Fig. 7.4).

7.6 Constraints Faced in the Cultivation of Reference Crops

All the farmers reported cultivation challenges due to weeds, pests and diseases. For weed control, traditional practices like summer ploughing and interculture are adopted by nearly all the farmers. Use of chemical sprays is resorted to by a number of farmers. None of the farmers are aware of any bio control method of controlling weeds, pests, and diseases (Table 7.18).

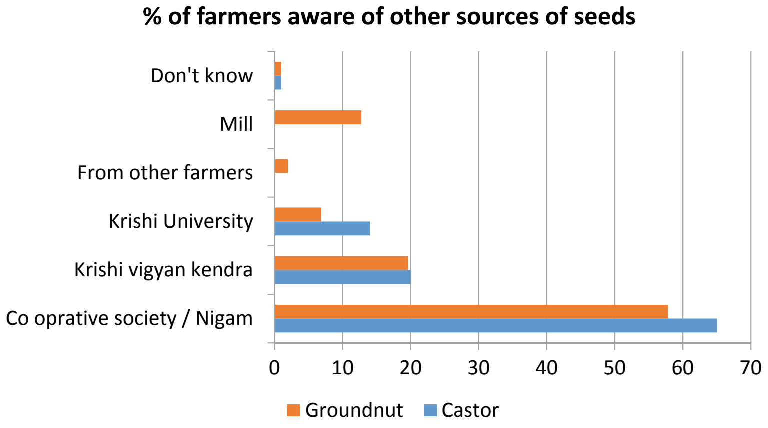

Fig. 7.4 Percentage of farmers aware of other sources of seeds. *Source* Farmer survey 2015

Table 7.18 Major constraints faced by castor farmers (%)

Major constraints	Yes	No
Problematic soil	32.5	67.5
Quality of seed	30.5	69.5
Availability of labor	72.4	27.6
Incidence of pests and diseases	95.6	4.4
Weeds	99	1
Water stress/salinity/fluoride	83.3	16.7
Cost of seed and availability	48.8	51.2
Cost of fertilizer and availability	60.1	39.9
Cost of pesticide and availability	57.6	42.4
Problems of the Wild animals	98	1
Others (electricity)	1.5	98.5

Source Farmer survey 2015

All farmers face a variety of constraints in cultivation. In terms of relative response, weeds, problems caused by wild animals, incidence of pests, salinity issue, availability of labor, price and availability of fertilizer, pesticides and seeds are the major issues have received more than 80% of the responses from farmers. Concerns on quality of seeds, cost and availability are reported by 31 and 49% of farmers. Electricity is not an issue for the castor farmers (Fig. 7.5).

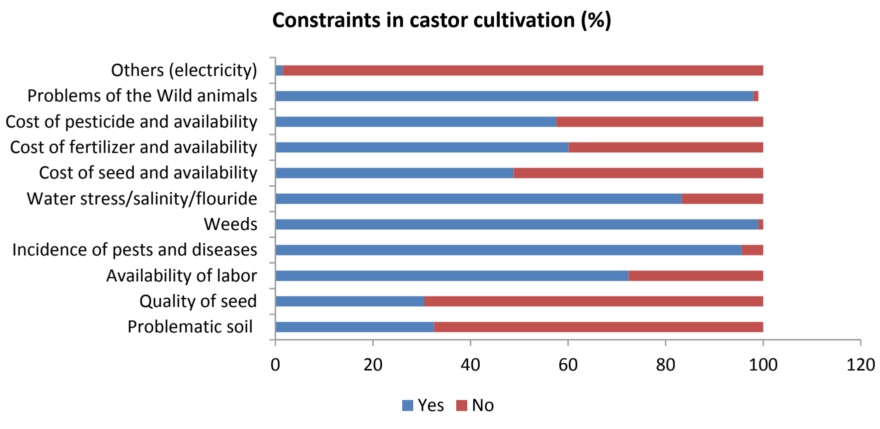

Fig. 7.5 Constraints in castor cultivation (%). *Source* Farmer survey 2015

7.6.1 Severity of Constraints Faced in Cultivation

Severity of constraints for the castor farmers rank high and medium with reference to weeds, water stress, and problems of wild animals. The severity of constraints range from medium to high in the case of quality of seeds, cost of and availability of seed and fertilizers for the castor cultivators (Table 7.19 and Fig. 7.6).

Table 7.19 Severity of constraints faced in castor cultivation (%)

Major constraints faced in the cultivation of castor	Low	Medium	High	N	% of total farmers reporting the constraint
Problematic soils	19.6	45.1	35.3	51	50
Quality of seed	22.6	61.3	16.1	31	31
Availability of labor	10.4	43.3	46.3	67	66
Incidence of pests and diseases	4.3	46.2	49.5	93	92
Weeds	4.0	32.0	64.0	100	99
Water stress/salinity/flouride	11.0	31.7	57.3	82	81
Cost of seed and availability	10.7	46.4	42.9	56	55
Cost of fertilizer and availability	3.2	39.7	57.1	63	62
Cost of pesticide and availability	19.6	50.0	30.4	56	55
Problems of the Wild animals		21.4	78.6	98	97
Others (electricity)			100.0	1	1

Source Farmer survey 2015

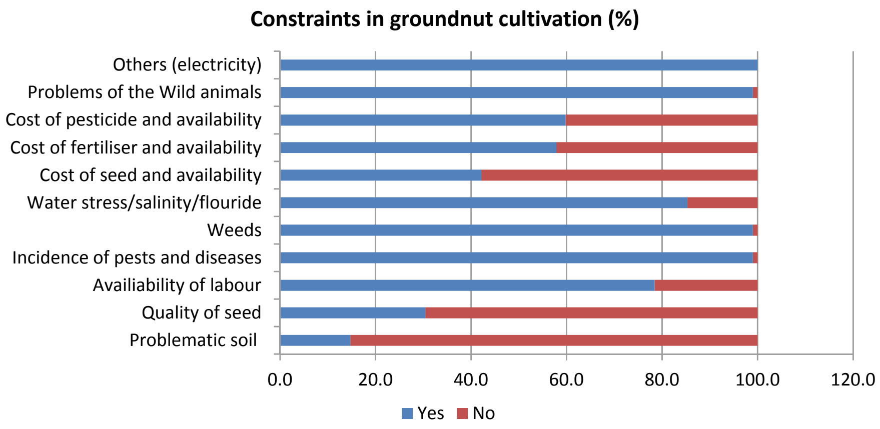

Fig. 7.6 Constraints in groundnut cultivation (%). *Source* Farmer survey 2015

Similar to the castor farmers, majority of ground nut farmers face serious cultivation challenges due to presence of weeds, incidence of pests, wild animals and water stress like salinity and fluoride content in water (Table 7.20).

Severity of constraints for the ground nut farmers ranges from high to medium in the case of water stress due to salinity/fluoride, wild animals, weeds, pests and diseases. Severity ranges from medium to high in type of soil, quality of seeds, cost

Table 7.20 Severity of constraints faced by ground nut cultivators (%)

Major constraints faced by Ground nut cultivators	Low	Medium	High	N	% of total farmers reporting the constraint
Problematic soils	33.3	60.0	6.7	15	15
Quality of seed	25.8	67.7	6.5	31	30
Availability of labor	10.4	43.3	46.3	80	78
Incidence of pests and diseases	3.0	46.5	50.5	101	99
Weeds	2.0	34.7	63.4	101	99
Water stress/salinity/flouride	2.3	20.7	77.0	87	85
Cost of seed and availability	25.6	53.5	20.9	43	42
Cost of fertiliser and availability	11.9	64.4	24.7	59	58
Cost of pesticide and availability	14.8	50.8	34.4	61	60
Problems of the Wild animals	1.0	7.9	91.1	101	99
Others (electricity)			100	2	2

Source Farmer survey 2015

and availability of pesticides, seeds, and fertilizers. Only two farmers said quality of electricity is an issue for them.

7.6.2 Occurrence of Weeds and Estimated Yield Loss

In the earlier section on constraints faced by farmers, more than 90% of the farmers growing both types of crops mentioned weed as one of the major issue. Survey results indicate that majority of the farmers indicating the problem to be medium and high in severity of incidence. Particularly for the castor farmers, weed issue persists both in kharif and rabi season, 46 different names of weeds that affect both the castor and ground nut cultivation were told by farmers (Table 7.21).

For the castor cultivators, yield loss due to weeds seems to occur more in the sowing, vegetative, and flowering stage. As castor is sown in June and the harvest goes on till end of March, farmers have reported problems to occur in both kharif and rabi season. Relatively more number of farmers is reporting yield losses at vegetative and flowering stage than sowing and grain formation stage, which may result in less number of reference plants per area. Importantly, the number of farmers reporting yield loss less than 5 and 10% is more than other categories. A very small percentage of farmers have reported higher yield loss (Table 7.22).

In the case of groundnut cultivators, yield loss due to weed happens only during the kharif season but during different stages of growth. The number of farmers reporting yield loss due to weeds during sowing and vegetative stage is almost the

Table 7.21 Yield loss reported by castor farmers

Stage of incidence of weeds		Yield loss due to weeds reported by farmers (%)			
Castor	Season	<5%	6–10%	11–20%	21–30%
Sowing	Kharif	89.5	96.3	100	100
	Rabi	10.5	3.7		
	N	19	27	11	4
Vegetative stage	Kharif	81.7	83.3	78.9	100
	Rabi	18.3	16.7	21.1	
	N	120	66	19	1
Flowering	Kharif	55.6	47.9	5.6	
	Rabi	44.4	52.1	94.4	100
	N	45	71	18	1
Grain	Kharif	7.1	8.1		
	Rabi	92.9	91.9	100.0	
	N	14	37	2	

Note Due to multiple responses, the N will not tally with the chosen number of farmers
Source Farmer survey 2015

Table 7.22 Yield loss realized by groundnut farmers

Stage of incidence of weeds		Yield loss due to weeds reported by farmers (%)			
Groundnut	Season	<5%	6–10%	11–20%	21–30%
Sowing	Kharif	97.9	92	100	
	Summer	2.1	8		
	N	142	25	2	
Vegetative State	Kharif	100	100	100	100
	N	145	46	12	1
Flowering	Kharif	100	89.5	100	
	Summer		10.5		
	N	33	19	7	

Note Due to multiple responses, the N will not tally with the chosen number of farmers
Source Farmer survey 2015

same, compared to the flowering stage. Implicitly, it may mean that some farmers have to resow or the yield could be less if weeds are not attended to at the right time. But, similar to the castor farmers, more number of ground nut farmers has reported yield loss of less than 5%, compared to farmers reporting yield loss of less than 10%.

7.6.3 Salinity and Drought Constraints Faced in Cultivation

In this section, we provide an analysis of farmers assessment about the salinity and drought constraints in production and estimated production loss. Majority of the castor (68%) and ground nut (74%) cultivators reported experiencing the salinity and drought affecting their production in the last 5–10 years. From the farmers' response, it appears that the salinity and drought issues though have been prevalent for more than 40 years, the incidence is felt more in the recent years. Particularly the percentage of castor farmers experiencing cultivation issues due to salinity in the recent years (less than 5 years) is also higher than the percentage of ground nut farmers reporting drought related issues.

During the primary survey farmers were asked to present production possibilities in three scenarios, viz (a) the absence of the salinity/drought related problem, (b) the presence of the salinity/drought related problem and (c) presence of salinity/drought related problem with remedial measures (Table 7.23 and Fig. 7.7).

In the following paragraphs, we analyse these scenarios.

In all, the farmers reported reduction in production that was ranging from 1 quintal to 80 quintals. Hence we have introduced the different slab structure for the production levels and the results are presented in the Appendix Table 7.31. In the absence of the salinity/drought issue, castor farmers have reported that they may get a yield (at the lower end) of 14.67 quintal per hectare or a total production of 2985 quintals.

Table 7.23 Production possibilities in the absence, presence and with the remedial measure for salinity/drought issue

		Number of farmers	Av. pron in qtl	Total pron in qtl	Quintal per hectare	Number of farmers	Av. pron in qtl	Total pron in qtl	Quintal per hectare
Absence of the salinity/drought issue	Castor	101	29.56	2985	14.67	101	37.75	3813	18.17
	Ground nut	102	19.3	1969	11.81	102	27.19	2774	16.6
	Aggregate	203	24.4	4954	13.4	203	32.45	6586	17.8
Presence of the salinity/drought issue	Castor	101	12.5	1262	6.2	101	18.03	1821	8.95
	Ground nut	102	7.57	772	4.63	102	11.91	1215	7.29
	Aggregate	203	10.02	2033	5.5	203	15	3036	8.2
Salinity/drought issue with a remedial measure	Castor	101	21.32	2153	10.6	101	28.15	2844	14
	Ground nut	102	12.86	1312	7.87	102	18.66	1903	11.41
	Aggregate	203	17.07	3465	9.4	203	23.4	4747	12.8

Source Farmer survey 2015

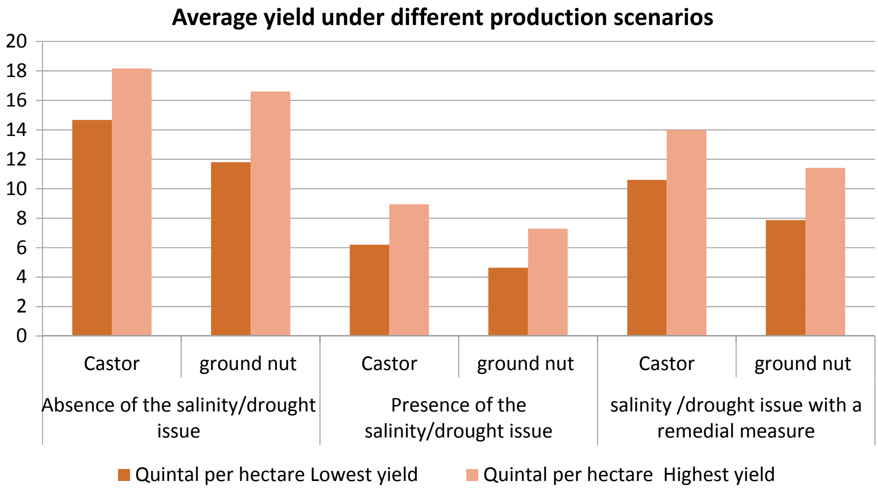

Fig. 7.7 Average yield under different production scenarios. *Source* Farmer survey 2015

In the absence of the problem, farmers might get a yield of 18.7 quintal per hectare or 3813 quintal on the higher side. Ground nut farmers were expecting 11.8 and 16.6 quintal per hectare in the absence of the salinity/drought issue.

In the presence of the salinity/drought issue, castor farmers were expecting a yield of 6.2 quintal on the lower end and 8.9 quintal on the higher side. Ground nut farmers were expecting 4.6 and 7.3 quintals on the either end of the production scenario. It appears from the responses, farmers did not expect that remedial measures for the salinity and drought issue would be available and those measures would restore their yield to the level prevailed when the problem was not present. Thus castor farmers expect a yield level of 10.6 and 14 quintals and ground nut farmers expect 7.8 and 11.4 quintal, which is much lower than the yield without the salinity/drought issue (Table 7.24).

Table 7.24 Farmers' suggestion about prices for the LMO output (%)

Price suggestion on the LMO output	Castor	Groundnut
Same as that of existing crop	5.9	5.9
1.25 times more	38.6	53.9
1.5 times more	35.6	24.5
2 times more	19.8	13.7
Don't know	0.0	2.0
Sum total	100	100
N	101	102

Source Farmer survey 2015

As farmers in general showed a positive awareness about LMOs and were also willing to pay a higher price for the seeds, we posed a question regarding their suggestion on prices for their LMO output. Farmers believed that output with a newer trait would get a higher price, hence except for 6% of the castor and ground nut growers who said that their output would be sold at the same price, 39 and 36% believed that their castor LMO output would be sold at a 1.25 or 1.5 times more than the prevailing price. Only 20% of the farmers said the price could be twice the existing price level.

In the case of ground nut cultivators, 54% believed that their LMO output would be priced 1.25 times more than the existing price and only 14 believed that the price could be double.

7.7 Health Issues Due to Pesticide Spraying

In all, farmers have used 856 sprays for pests and 371 sprays for the weeds, rendering a total of 1227 chemical sprays. A total of 371 and 856 sprays have been applied to control weeds, pests and diseases in castor and ground nut. Ground nut farmers have used 241 and 618 sprays to control weeds and pests compared to 130 and 238 sprays used by castor farmers (Table 7.25).

Share of ground nut farmers is high with 5.2 chemical sprays per hectare compared to 1.8 sprays per hectare by the castor farmers. Given that ground nut is an edible product, the number of chemicals used is a cause of concern for the health of consumers, workers, environment, animals which are fed on ground nut cakes, and soil health.

As 93% of the farmers spray pesticide by themselves, their exposure to direct inhalation while spraying would be more. However, only 20 farmers reported any side effect of which majority suffered from eye and skin irritation (Table 7.26).

The analysis implies that workers feel sick but not severe enough to seek treatment, but they perhaps withdraw themselves from work on those days. Thus farmers have lost 111 working days fully and 31 days due to average reduction in working hours due to illness. Together, these 20 farmers have lost 142 working days. As all these farmers have reportedly working only in their own farm, the implication of working

Table 7.25 Total number of sprays in castor and ground nut cultivation

	Castor	Groundnut
Land in hectare	203.5	166.6
Total chemical sprays	368	859
Number of pest sprays	238 (82)	618 (102)
Number of weed sprays	130 (60)	241 (65)
Per hectare chemical spray	1.8	5.2

Note Figures in parentheses indicate the number of farmers
Source Farmer survey 2015

Table 7.26 Number of working days lost due to illness

Health impairment	No. of working days lost in full due to illness (per year) 1	Average reduction in working hours per days due to illness 2	Total days lost 3[a]	Total working days lost 2 (col 1+col 3)
Nausea	8	30	3.8	12
Severe cold	4	3	0.4	4
Eye irritation	48	94	11.8	60
General weakness	7	30	3.8	11
Sleeplessness	1	1	0.1	1
Skin irritation	41	88	11.0	52
Others	2	2	0.3	2
Total	111	248	31.0	142
N	20	20		

Note [a]Reduction in working hours have been converted into mandays
Source Farmer survey 2015

days lost is on delayed attending to their farm activities and productivity. A total cost of Rs. 4560 has been incurred by these farmers to address the health issues, out of which 41% has been spent on medicines and the rest has been spent on physicians' fee and transportation (Fig. 7.8).

Farmers generally have not received any training on the use of pesticides. Hence use of protective clothing, use of gloves, covering nose or mouth to prevent direct inhaling of pesticides seem to be practiced by a few. While very few farmers reported that they do eat while spraying, smoking while spraying is widely prevalent. Nearly

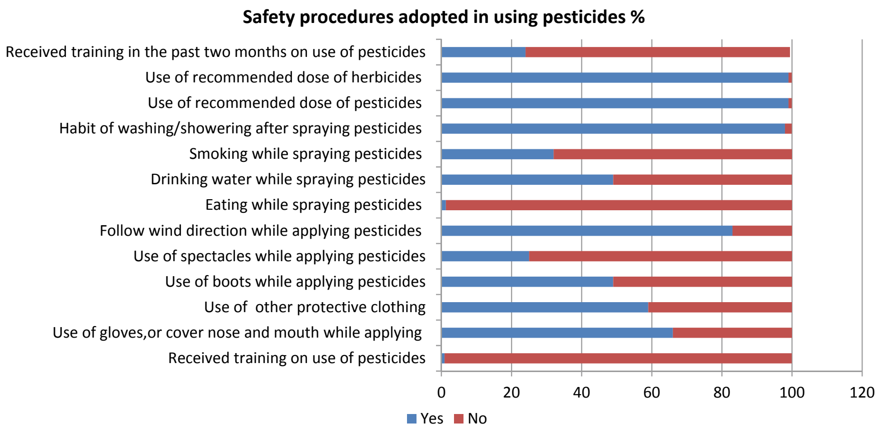

Fig. 7.8 Safety procedures adopted in using pesticides (%). *Source* Farmer survey 2015

99% of the farmers said that they are using the recommended dose of pesticides in their farming. More than 50% of the farmers reported disposing of the empty pesticide containers in scrap.

7.8 Farmers' Knowledge About GMOs

Figure 7.9 provides the percentage of farmers' response to questions related to their knowledge about GMOs, which is overall positive regarding the adoption of GMO with newer traits, returns, probable health and environmental impact. Farmers were more familiar with Bt cotton (91%) and brinjal (6%) than about tomato (0.8%) or cabbage (2.4%) or any other crops.

7.8.1 Experience with Bt Cotton

Though, more than 60% of the farmers said that they know about GM crops, about 35% of the total farmers have actually cultivated Bt cotton. The percentage is slightly lower because, the interviewed farmers have been mainly cultivating castor and ground nut. More than 95% of the cotton cultivators said that they received higher yield which ranged from 2 to 30%. However, 37, 27 and 18% of this sub group of cotton cultivators said that they got higher yield by 5, 10 and 15% respectively. 51 farmers or closer to 70% of this sub group of cotton cultivators (68 farmers) said that they had to use higher inputs, the cost of which ranged from Rs. 1000 to Rs. 15,000. Specifically, percentage of farmers who reported an increase in the input

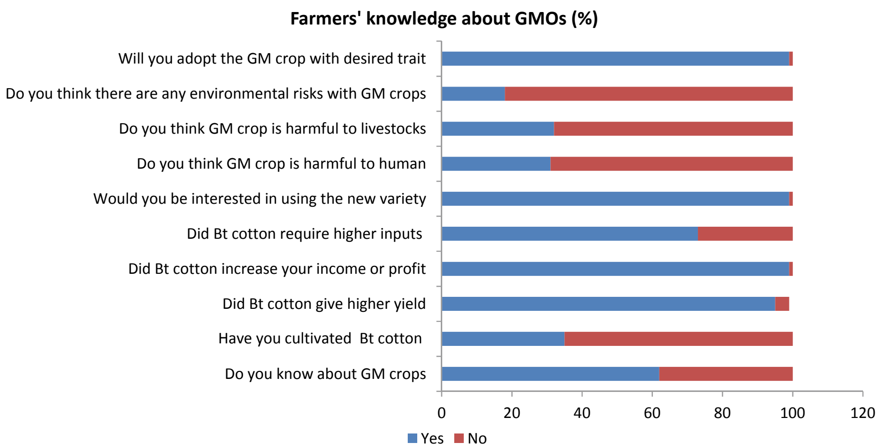

Fig. 7.9 Farmers' knowledge about GMOs (%). *Source* Farmer survey 2015

Table 7.27 Farmers willingness to pay for the trait (%)

Willingness to pay more for the new trait	All farmers	Castor farmers	Ground nut farmers
<10% of the price paid in the last season	17	22.8	11.1
10–25% of the price paid in the last season	49	42.6	55.6
25–50% of the price paid in the last season	23.5	22.8	24.2
>50% of the price paid in the last season	10.5	11.9	9.1
Sum total	100	100	100
N	200	101	99

Source Farmer survey 2015

expenditure by Rs. 1000 (27%), Rs. 2000 (27%) and Rs. 3000 (11%) were more than other farmers who reported higher input expenditure.

7.8.2 Willingness to Pay for the New Trait

98.5 per cent of all the farmers said that they would be willing to pay for the seed with the desired trait. 100 and 97 per cent of the castor and ground nut growers respectively were willing to pay for the new trait.

17, 49, 24 and 10.5 per cent of farmers respectively were willing to pay less than 10%, 10–25% more, 25–50% more and more than 50% of the price that they had paid in the last season. Majority of the castor and ground nut farmers were willing to pay 10–25% more price than what they paid during the last crop season (Table 7.27).

7.8.3 Reasons for Adopting GM Crop with New Trait

It is evident from the Table 7.28 that majority of farmers (59%) are willing to adopt a GM crop with new trait for the sake of experience and learn from their experience. This response even precedes their eagerness to gain more production from the new variety.

Table 7.28 Reasons for adopting GM crop (%)

Reason for adopting the proposed GM crop with desired trait	Crop		
	Castor	Groundnut	Total
For experience	66.3	50.5	58.5
More production	22.8	34.3	28.5
To address the pest issue	4.0	9.1	6.5
Needs less water	2.0	4.0	3
Should provide more branches for bearing fruits	3.0		1.5
Salinity but they grow	2.0		1
Good quality		1.0	0.5
Get good price		1.0	0.5
Sum total	100.0	100.0	100
N	101	99	200

Source Farmer survey 2015

7.8.4 *Other Preferred GM Traits*

When posed with the question of what are the different GMO traits that the farmers would prefer, 42 and 39% of them said a trait that would yield more and provide respite from pests would be preferred by them. Interestingly, the ground nut farmers are relatively more aware of genetic modification and aware of Bt cotton grown in their area. They also seek information on market preferences and market price behaviors before planting (Fig. 7.10).

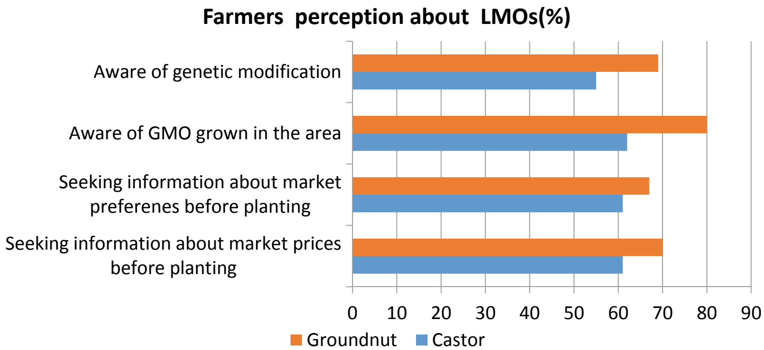

Fig. 7.10 Farmers perception about LMOs (%). *Source* Farmer survey 2015

7.9 Risk Perception About GMOs

A set of questions were asked to farmers to provide their views on the risks associated with GM crops from (1) farming perspective, (2) food security, (3 health risks for human and livestock (4) bio diversity and environment, (5) corporate control, and (6) regulatory issues, which are discussed below.

1. 91 per cent of the farmers agreed that GM crops are beneficial for farmers and GM seeds tend to reduce the cost of cultivation. 73 per cent of farmers agreed that GM technology is required for a few crops.
2. 83 per cent of the farmers believed that GM crops will ensure food security for the growing population. But farmers were equally divided on their view on the GM pollen contamination.
3. 67 per cent of the farmers did not believe the GM crops will cause harm to humans and cattle and 65% of farmers did not agree that GM in food chain could be a health risk.
4. 97 per cent of the farmers did believe that GM crops increase the monopoly of big companies in the seed market.
5. Though 94% of farmers believed that scientific tests were done prior to release of GM crops, 66% also believed that scientists tend to conceal data on harmful effect of GMOs and GM crops will benefit only farmers with large-sized holdings.
6. 68 per cent of farmers agreed that GM technology will cripple their traditional cultural practices.
7. 99 per cent agreed that GM foods should be labeled for the benefit of consumers
8. 83 per cent of the farmers believed that information on GM in mass media is trust worthy (Govt will have to carefully weigh the information that gets passed on to the farmers in the vernacular languages).
9. 64 per cent of the farmers agreed that secondary pests will increase after GM crop cultivation (Table 7.29).

7.9.1 Information Seeking Behavior of Farmers

26 and 23 per cent of the castor and ground nut producers said that they received advice or training from different sources in the last two seasons. 75 per cent of the farmers said that they do not get any information from any service provider. More than 65% of the farmers sought market prices and preferences before they planted. However, there were very few responses on the information sought for farming practices.

Table 7.29 Risk perception of farmers (%)

Details	Strongly agree	Agree	Some what agree	Disagree	Strongly disagree
GM crops like Bt cotton will be beneficial for farmers	14	64	13	6	2
Adoption of GM seeds will reduce the cost of cultivation	6	35	30	24	4
Cultivation of GM crops will ensure food security for the rapidly growing population	6	41	36	14	2
Cultivation of GM crops will be risky as pollen flow from GM plants will contaminate other neighboring crops	4	19	26	41	9
Since GM crops carry genes from different species they will cause harm to the human and cattle	8	22	2	48	19
Entry of GM food in food chain will cause health risk	8	24	2	41	25
Cultivation of GM crops will harm agro- biodiversity	5	13	6	55	21
The production and trade of GM seeds will increase the monopoly of big companies in the seed market	21	47	29	2	0
GM technology is required for few crops	10	48	15	22	4
Rigorous scientific testing is done prior to release of GM crops	26	44	24	4	2
Genetic engineering scientists tend to conceal data about harmful effects of GMOs	5	17	44	27	6
Only the large farmers will be befitted by genetic engineering technology	6	33	21	30	11
Promotion of GM technology will cripple indigenous knowledge system	15	44	9	27	5
Promotion of GM crops will pose a serious threat to GI marked high value crops (e.g. Basmati rice)	7	49	32	10	1
Genetically modified foods should be labeled for the benefit of consumers	31	63	5	0	
Information on biotechnology provided by mass media sources is trustworthy	17	28	38	12	6
Prevalence of secondary pests will increase	6	25	33	33	2

Source Farmer survey 2015

7.10 Summary and Conclusion

In this section, along with the summary, implications of certain identified trends are presented.

1. ***Profile of farmers***: The average age of the castor, ground nut and all farmers are 44, 46 and 45 years respectively. Implicitly, it indicates the relatively less involvement of younger generation in agriculture.
2. Nearly 88% of the farmers have primary or secondary education.
3. Of the 1170 household members, 56% of the household is engaged in farming which consists of 57 and 43% of male and female respectively.
4. The average size of the household of the sample farmers is 5.7 members.
5. Of the total 203 farmers chosen for the study, 56, 38 and 6.4 constitute the small, medium and large land holders respectively.
6. 92.5 per cent of the total income comes from agriculture and the rest from other sources.

Irrigation Status of Land Held by Farmers
Totally 95% of the land is irrigated. Tube well irrigates 81% of the area and 17.6% by open wells. Majority of the tube wells have been dug after 2000. In addition to the recent infrequent rainfall in Gujarat, digging of more tube wells could contribute to the fast depletion of ground water resources.

Labor Use in Castor and Ground Nut Cultivation
A total of 28,924 person days have been used in cultivation by the chosen farmers. Of this 47% has been contributed by the family labor. Females constitute 33% of the total labor force. Hired labor constitutes 25% of the total labor force. Farmers report a yield of 23 quintals in castor and 15 quintals in ground nut.

Indebtedness
68 percent of the farmers reported availing loans for regular farming expenses and capital expenditures. Top most purpose reported was seed purchase followed by other inputs. Hence, timely availability of loan is essential. If the farmers are unable to get timely loan, they may miss the season or may not be able to get their choice of seeds. This can also push the farmers in vulnerable situations. Farmers depend on formal sources for their loan needs and particularly on cooperative more than the commercial banks.

7.10.1 Cost of Cultivation

On an average, the study farmers used 382 kg of fertilizers. 4.5 and 120 kg of castor and ground nut seeds have been used in cultivation. Rs. 454 and Rs. 1082 per hectare have been spent on pesticides by castor and ground nut producers.

Farmers have incurred a total cost (paid out cost) of Rs. 52,657 per hectare at aggregate level. The per hectare cost of producing castor and ground nut amounts to Rs. 46,615 and Rs. 56,833 respectively. At the aggregate level and for the individual crops, cost of hiring machines for land preparation is higher than the cost of machinery reported for other operations. Material input costs are higher particularly for fertilisers (28%) followed by seeds (12.8%) and pesticides (8.9%) for the ground nut farmers. In weeding and harvesting, per hectare cost comprises mainly of the labor costs. Cost of electricity for irrigation is substantial in the total cost per hectare, mainly due to the relatively high tariff structure prevailing in Gujarat.

Castor and ground nut farmers have earned a gross income of Rs. 79,151 and 60,165 per hectare. After all the paid out costs, castor and ground nut farmers have received a net income of Rs. 32,535 and 3332 per hectare respectively.

The crop income of the chosen farmers is partially determined by the use of F1 seeds and irrigation status of the farmers. The analysis reveals that the mean difference in the crop income earned per hectare by the castor and ground nut farmers is positive and significant, while there is no significant difference in the paid out costs per hectare incurred by castor and ground nut cultivators.

Constraints in Cultivation

Severity of constraints for the castor farmers rank high and medium with reference to weeds, water stress, and problems of wild animals respectively. Severity of constraints for the ground nut farmers ranges from high to medium in the case of water stress due to salinity/fluoride, wild animals, weeds, pests and diseases.

For the castor cultivators, yield loss due to weeds seems to occur more in the sowing, vegetative and flowering stage. In the case of groundnut cultivators, yield loss due to weed happens during different stages of growth.

Benefit cost scenario

For castor and ground nut farmers, the initial Benefit cost ratios (BCR) stood at 1.698 and 1.059. The BCR analysis for ground nut farmers suggests that an increase in yield level of at least up to 20% is essential, if the seeds with the newer trait for drought tolerance is offered at 25% more than the prevailing price level. With the 20% increase in the yield the farmers will not be worse off than their initial level of benefits.

For the castor farmers in Gujarat, perhaps because of the higher yield level, the subsequent increase in the yield and price of the seeds do not make them worse off than their starting level of benefits. BCR of the castor farmers is more than their initial levels of benefits even at 5% increase in the yield and at different increased price level.

Production Scenarios Without, with and Along with Remedial Measures for Salinity/Drought Issue

In the presence of the salinity/drought issue, castor farmers were expecting a yield of 6.2 quintal on the lower end and 8.9 quintal on the higher side. Ground nut farmers were expecting 4.6 and 7.3 quintals on the either end of the production scenario. It appears from the responses, farmers do not expect that remedial measures for the salinity and drought issue would restore their yield to the level in the absence of the problem. Thus castor farmers expect a yield level of 10.6 and 14 quintals and ground nut farmers expect 7.8 and 11.4 quintal, which is much lower than the yield without the salinity/drought issue.

Environment Related

Each castor farmer irrigates their farm 10.6 times during the course of castor cultivation and each ground nut farmer irrigated their farm 3.32 times during the ground nut season. As more than 80% of the farmers are using tube well, it implies a lot on ground water extraction, which can hasten the salinity ingress and add to the drought scenario as well. It may be noted that 68 and 73.5% of the castor and ground nut farmers experienced the salinity/drought related issues more in the last 5 to 10 years, which also coincides with more farmers reporting digging up tube wells.

As farmers depend on non-renewable source of energy, the carbon foot print in the production of castor and groundnut could also be higher than other crops.

Pesticide Use

In all, farmers have used 856 sprays for pests and 371 sprays for the weeds, rendering a total of 1227 chemical sprays. Ground nut farmers have used 241 and 618 sprays to control weeds and pests compared to 130 and 238 sprays used by castor farmers.

Ground nut farmers reported using more number of sprays which is a concern from health and environment point of view. Though farmers reported using recommended dose of pesticides, the self safety measures need to be improved. Only a few farmers have reported illness due to mild poisoning of pesticides. The long term health implications could be different.

Knowledge About GM Crops

Farmers were more familiar with Bt cotton (91%) and brinjal (6%) than about any other crops. 98.5% of the farmers were willing to use the new variety with the desired trait. Out of the 30% of farmers who had adopted Bt cotton, more than 90% had received positive income through Bt cultivation. 98% of the farmers were willing to pay for the new variety and majority were willing to pay 10–50% higher price than what they would pay for a conventional variety.

Risk Perception About GMOs

91 per cent of the farmers agreed that GM crops are beneficial for farmers and GM seeds tend to reduce the cost of cultivation. 73 per cent of farmers agreed that GM technology is required for a few crops. More than 75% of the farmers did not think that GMOs pose an environmental risk.

83 per cent of the farmers believed that GM crops will ensure food security for the growing population. But farmers were equally divided on their view on the GM pollen contamination. 80 per cent of the farmers also believed that GM crops would be required to address the issue of food security.

Overall, this analysis indicated that there is scope for introducing LMOs in castor and ground nut as indicated by the farmers' willingness to adopt them. While this is a positive indication, there are also fears about the scientific information about GMOs and monopoly position of companies. This signals that there is a need for the scientists to communicate frequently to the farmers about the LMOs. Newer traits in open pollinated varieties than hybrids would reduce the costs and also more adoption. Similarly, while farmers have benefitted by the increased yield and income due to Bt adoption, they had also incurred increased expenditure. Extension services toward rational use of inputs could help in the reduction of costs. Bt cotton adoption in India actually demonstrates that besides introducing technologies, India also requires governance mechanisms and institutions to disseminate information to reap maximum benefits from a technology that is the result of several years of research and resources.

7.11 Policy Implications of Select SE Aspects

1. ***Perception of farmers about LMOs*** Farmers are positive about the need of technology and its usefulness in increasing production and addressing food security. More than 95% of the farmers are also willing to adopt the newer traits.
2. ***Traditional cultural practices*** 1. One of the common fears of impact of technology is about the loss of traditional varieties and knowledge. In the case of castor all the farmers are relying on the market. Hence, the possibility of the fear that GMO castor replacing the traditional varieties is ruled out as the traditional varieties are not used any more. However, 38% of ground nut cultivators still use the farm saved variety and hence a LMO ground nut introduction may pose an issue. But in both the crops and as a practice in general, if LMOs are available in traditional varieties rather than hybrids, it would have more adoption as well as positive cost reduction for farmers. 2. To address pests and diseases and weeds, though farmers are adopting intercultural practices like summer ploughing, they are also dependent on chemical sprays for reducing the same. Hence, there is need for more information flow to the farmers about the management of pests and weeds.

3. ***Livelihood opportunities*** Salinity and drought resistant varieties would ensure that farming is possible in adverse situation also and farmers would not leave agriculture. Hence, it would have positive impact on farm employment. Also it indicates sustainability of livelihood as with newer varieties farmers can continue farming during drought situations as well.
4. ***Environment related*** Drought-tolerant varieties could mean that they require less water. Hence, if farmers are given an option to adopt this variety, farmers' dependency on tube well would reduce. It has positive implication on environment as ground water drawn would reduce as well as on the energy use as the electricity consumption would reduce. Introduction of pest resistant varieties would result in reduced number of sprays on crops and environment. Particularly in the present study, as the ground nut farmers use more pesticide sprays, the residues of the same in an edible crop like ground nut could be a cause for concern and reduction in the same would be beneficial for the health of environment and for farmers.
5. ***Potential impact on livestock*** Presently in both the castor and ground nut crops, the farmers are not engaged in making any value addition of the byproducts but sell the harvested products to other stake holders for making value addition. But one of the byproducts, viz the oil cakes of both the products are used as animal feed. Hence, the safety of the byproducts needs to be assessed and made known widely to remove the fears in the minds of farmers and consumers.
6. ***Labeling requirements*** Both castor and ground nut are consumed by humans. Castor oil is used as a medicine and as a preservation element to store the processed food grain for long (particularly in Gujarat). Castor oil is also used in cosmetics. Both ground nut and ground nut oil are consumed by humans. Hence, consumers may prefer labeling on the packs. The other food related regulatory requirement for LMO need to be set up.
7. ***Export markets*** Ground nut and castor are two important products of Gujarat with a relative comparative advantage (RCA) in total exports of Gujarat at 1.9 and 4.33 (Dholakia[5] 2002). Hence, the preference of the consumers for LMO products in those countries also needs to be taken into account.
8. ***Production possibilities with traits*** While obviously the production estimates in the absence of the salinity/drought is maximum, it is evident that farmers did not think that a scientific solution to salinity and drought would be a possibility. Hence, their production estimates with remedial measures were lower than the estimates for a scenario in which no issues related to traits would be present. This particular aspect necessitates that lots of extension activities will have to take place to help the farmers know and adopt the technology.
9. ***Benefit scenarios*** The benefit cost scenarios constructed show that the ground nut farmers require at least 20% yield increase to bear any increased cost of seeds (assuming other costs remaining the same). Hence, it warrants appropri-

[5]These values increase to 4.3 and 9.77 when the RCA was calculated excluding the gems and jewelry exports from Gujarat http://www.iimahd.ernet.in/publications/data/2002-09-05RavindraHDholakia.pdf.

ate pricing strategies. But in reality, as other costs would also to be incurred by farmers, yield enhancement through seeds as well as through better farm management practices should be emphasized to ensure that farmers do not leave agriculture due to cost escalation.

10. ***Loan for farmers*** We note that loan for buying seeds has been the prime most reason for all farmers and for castor and ground nut cultivators followed by purchase of pesticides and fertilizers. Hence, timely availability of the loan would enable to meet the crop season.
11. ***Knowledge about Bt*** Majority of the farmers are positively inclined about the technology, in terms of the yield and increased income and profit. However, they also reported the need for higher inputs. Perhaps if the need for inputs was lower, their profits would be manifold. This suggests that whenever a new trait option is provided to the farmers, it should not be sold only as a seed technology but as a combination of practices like appropriate use of plant protection mechanisms and plant nutrients. This will have multiple benefits via reduction in costs, improved farmers' health and environment.
12. ***Safe use of pesticides*** As in the present study, the farmers themselves have been spraying pesticides but adoption of safety measures is not practiced by all uniformly. A few have reported observed illness. While minor illnesses might be ignored by farmers, yet the potential long term health hazards on farmers cannot be ruled out. At the same time use of protective clothing will not be adhered by all due to the climatic conditions. Hence, doable minimum like using protective clothing while mixing the chemicals, observing wind direction and use of required dose and at required time need to be emphasized.
13. ***Public–private partnership*** Public–private partnership in seed development would check the monopolistic pricing of seeds and position of companies. PPP should be the preferred mode for introducing open pollinated varieties.
14. ***Diffusion strategies*** Most agri biotechnologies might probably reach the farmers in seed form. However, in order to ensure longevity of the shelf life of the technology, it is essential, diffusion strategies are sequenced. This necessitates the revival of the age old extension system.
15. ***Regulation and governance*** Appropriate governance structures need to be set up to ensure technology is adopted and to get feedback from farmers before and after adoption for any intervention.

Overall, this analysis indicated that there is scope for introducing LMOs in castor and ground nut as indicated by the farmers' willingness to adopt them. While this is a positive indication, farmers' perceptions also revealed that apprehensions about scientific information and relied more on information from mass media. In the absence of information from sources like universities and government, farmers believe in the media supplied information. This signals that there is a need for the scientists to communicate frequently to the farmers about the LMOs and remove the fear of unknowns. Similarly, while farmers have benefitted by the increased yield and income due to Bt adoption, they had also incurred increased expenditure. Extension services toward rational use of inputs could help in the reduction of costs and improved farm income.

Unlike other GM crops elsewhere, Bt adoption in India showed that technology adoption is scale neutral and hence India has to learn from her own lessons from Bt adoption that would best serve as ex ante strategy. In the case of Bt cotton in India, availability of non-Bt seeds became limited and therefore the options before the non-Bt farmers were limited and they were left with either to shift to other crops or adopt GM cotton. Hence to avoid such a scenario, the flexibility to return to conventional cultivation should remain open for farmers. Bt cotton adoption in India actually demonstrates that besides introducing technologies, India also requires governance mechanisms and institutions to disseminate information to reap maximum benefits from a technology that is the result of several years of research and resources.

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Appendix

See Tables 7.30 and 7.31.

Table 7.30 Cross correlations matrix

	Seed cost per hectare	Irrigation (electric bill) cost per hectare	Fertilizer cost per hectare	Pesticide cost per hectare	Yield per hectare in quintal	Have tractor = 1 no 0	Seed bought yes = 1 no 0	Pestcide quantity used per hectare	Fertiliser quantity used per hectare	Seed quantity used per hectare	Crop income per hectare	Log of cropincome per hectare	Hired labor cost per hectare	Chemical sprays per hectare
Seed cost per hectare	1													
Irrigation cost per hectare	−.144*	1												
Fertilizer cost per hectare	0.014	0.103	1											
Pesticide cost per hectare	0.376**	−0.13	−0.026	1										
Yield per hectare in quintal	−.342**	0.326**	0.012	−.224**	1									

(continued)

Table 7.30 (continued)

	Seed cost per hectare	Irrigation (electric bill) cost per hectare	Fertilizer cost per hectare	Pesticide cost per hectare	Yield per hectare in quintal	Have tractor = 1 no 0	Seed bought yes = 1 no 0	Pestcide quantity used per hectare	Fertiliser quantity used per hectare	Seed quantity used per hectare	Crop income per hectare	Log of cropincome per hectare	Hired labor cost per hectare	Chemical sprays per hectare
Have tractor = 1 no 0	−0.067	−0.053	−0.023	−0.032	0.153*	1								
Seed bought yes = 1 no 0	0.403**	0.172*	0.097	−.191**	0.181**	0.220**	1							
Pestcide quantity used per hectare	−0.015	0.176*	0.007	0.128	0.115	−0.055	0.085	1						
Fertiliser quantity used per hectare	−0.101	0.109	0.594**	−0.083	0.062	0.018	0.051	0.056	1					
Seed quantity used per hectare	0.916**	−0.184*	−0.07	0.426**	−.393**	−0.062	0.343**	−0.057	−0.179*	1				

(continued)

Table 7.30 (continued)

	Seed cost per hectare	Irrigation (electric bill) cost per hectare	Fertilizer cost per hectare	Pesticide cost per hectare	Yield per hectare in quintal	Have tractor = 1 no 0	Seed bought yes = 1 no 0	Pestcide quantity used per hectare	Fertiliser quantity used per hectare	Seed quantity used per hectare	Crop income per hectare	Log of cropincome per hectare	Hired labor cost per hectare	Chemical sprays per hectare
Crop income per hectare	−.279**	0.341**	0.06	−.174*	0.845**	0.151*	0.239**	0.114	0.12	0.330**	1			
Log of crop income per hectare	−.278**	0.272**	0.009	−0.163*	0.695**	0.144*	0.185**	0.088	0.082	−.296**	0.907**	1		
Hired labour cost per hectare	0.167*	0.176*	0.283**	0.146*	0.05	−0.065	−0.022	0.116	0.289**	0.023	0.063	−0.001	1	
Chemical sprays per hectare	0.242**	−0.02	0.093	0.623**	−0.139*	−.236**	−.311**	0.201**	0.088	0.256**	−0.13	−0.180*	0.386**	1
	203	203	203	203	203	203	203	203	203	203	203	203	203	203

Note * and ** indicate the significance of correlation at 5 and 1 per cent level respectively
Source Farmer survey 2015

Table 7.31 Production scenarios in the absence, presence and with a remedial measure for the problem

Absence of the salinity/drought issue						
Lowest production in quintal per hectare				Highest production in quintal		
Production in quintal	Percentage of farmers	Average production in quintal	Total production in quintal	Percentage of farmers	Average production in quintal	Total production in quintal
Castor						
<10.00	3.0	8.03	24	0	0	0
10.01–20.00	12.9	18.05	235	2	14.82	30
20.01–30.00	37.6	26.45	1005	19	27.01	513
30.01–40.00	40.6	34.29	1406	49	36.09	1768
40.01 above	5.9	52.61	316	31	48.43	1501
Sum total	100.0					
N	101.0	29.56	2985	101	37.75	3813
Per hectare production			14.7			18.7
Groundnut						
<10.00	2.9	6.18	19	1	0	0
10.01–20.00	65.7	15.96	1070	21	17.41	366
20.01–30.00	19.6	24.27	485	37	24.7	914
30.01–40.00	10.8	31.44	346	40	33.19	1328
40.01 above	1.0	49.4	49	3	55.58	167
Sum total	100.0					
N	102.0	19.3	1969	102	27.19	2774
Per hectare production			11.8			16.6
Total						
<10.00	3.0	7.1	43	1	0	0
10.01–20.00	39.4	16.3	1304	23	17.18	395
20.01–30.00	28.6	25.7	1490	56	25.48	1427
30.01–40.00	25.6	33.68	1752	89	34.79	3096
40.01 Above	3.4	52.15	365	34	49.06	1668
Sum total	100.0					
N	203.0	24.4	4954	203	32.45	6586
Per hectare production			13.4			17.8

(continued)

Table 7.31 (continued)

Presence of the salinity and drought issue+remedial measure						
Lowest production in quintal per hectare				Highest production in quintal		
Production in quintal	Percentage of farmers	Average production in quintal	Total production in quintal	Percentage of farmers	Average production in quintal	Total production in quintal
Castor						
<10.00	48.5	7.06	346	19	9.06	172
10.01–20.00	38.6	15.79	616	44	16.28	716
20.01–30.00	11.9	22.12	265	35	23.76	832
30.01–40.00	1.0	34.58	35	3	33.63	101
Sum total	100.0					
N	101.0	12.49	1262	101	18.03	1821
Per hectare production			6.2			8.9
<10.00	80.4	6.13	503	41	7.8	320
Groundnut						
10.01–20.00	19.6	13.46	269	58	14.2	824
Sum total	100.0			3	23.88	72
N	102.0	7.57	772	102	11.91	1215
Per hectare production			4.6			7.3
Total						
<10.00	64.5	6.48	848	60	8.2	492
10.01–20.00	29.1	15	885	102	15.1	1540
20.01–30.00	5.9	22.12	265	38	23.77	903
30.01–40.00	0.5	34.58	35	3	33.63	101
Sum total	100					
N	203	10.02	2033	203	14.96	3036
Per hectare production			5.5			8.2
Presence of the salinity and drought issue+remedial measure						
Lowest production in quintal per hectare				Highest production in quintal		
Production in quintal	Percentage of farmers	Average production in quintal	Total production in quintal	Percentage of farmers	Average production in quintal	Total production in quintal
Castor						
<10.00	13.9	9.1	127	1	9.9	10
10.01–20.00	34.7	16.59	581	21	17.1	359
20.01–30.00	35.6	25.35	913	34	25.3	860

(continued)

Table 7.31 (continued)

Presence of the salinity and drought issue+remedial measure						
Lowest production in quintal per hectare				Highest production in quintal		
Production in quintal	Percentage of farmers	Average production in quintal	Total production in quintal	Percentage of farmers	Average production in quintal	Total production in quintal
30.01–40.00	15.8	33.27	532	38	34.3	1302
Sum total	100.0			7	44.7	313
N	101.0	21.32	2153	101	28.2	2844
			10.6			14.0
Groundnut						
<10.00	23.5	7.56	182	2	9.3	19
10.01–20.00	69.6	13.52	960	74	16.4	1216
20.01–30.00	6.9	24.35	170	19	23.8	452
Sum total	100.0			7	30.9	216
N	102.0	12.86	1312	102	18.7	1903
			7.9			11.4
Total						
<10.00	18.7	8.13	309	3	9.5	28
10.01–20.00	52.2	14.53	1540	95	16.6	1575
20.01–30.00	21.2	25.19	1083	53	24.8	1312
30.01–40.00	7.9	33.27	532	45	33.7	1518
Sum total	100			7	44.7	313
N	203	17.07	3465	203	23.4	4747
			9.4			12.8

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Chapter 8
Socioeconomic Assessment of Living Modified Organisms (LMOs) in North Karnataka

Suresh S. Patil, Yasmeen and Ravindra Chavan

Abstract The present study was carried out to assess the socioeconomic implications of LMOs i.e. Bt cotton in comparison to traditional or pigeon pea in North Karnataka. The primary data for the study was collected from different stakeholders related to Bt cotton (LMOs) cultivation *viz.*, farmers (150), farm labourers (50), traders/input dealers (25) and academicians/researchers (25). The results revealed that more employment opportunities were provided for both (men and women) labourers in the case of Bt Cotton (LMO) crop as compared to pigeon pea and non-Bt cotton. Study also found that the area under Bt cotton crop cultivation has increased over the years. The extent of application of plant protection chemicals was relatively higher in case of non-Bt cotton as compared to Bt cotton. The net return accrued was also higher in Bt cotton (Rs. 12453.05), which was mainly due to higher level of yield. The returns to per rupee of investment were found to be higher in the case of Bt cotton (1.38) as compared to pigeon pea (1.17) and non-Bt cotton crop (1.18). Study also found that the farmers showed favourable inclination towards the LMOs and they are ready to accept if LMO trait is brought in pigeon pea as well, provided it should be scientifically proved that it will not be harming the livestock.

Keywords Bt cotton · Cultivation · Living modified organism · Net return and yield

8.1 Introduction

The living organisms which possess a novel combination of genetic material obtained through the use of modern biotechnology are referred to as Living Modified Organism (LMOs) or Genetically Modified Organism (GMOs). The LMOs of major economic crops, specifically soybean, maize, rape (canola) and cotton, were first grown commercially in 1996. Since 1996, when farmers first commercially planted LMOs, the area under these crops has raised more than hundredfold from 1.7 m ha to 181.5 m ha

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(from 1996 to 2014). Currently, the global area of LMO crops continued to increase for the 19th year at a sustained growth rate of 3 to 4 percent or 6.3 million hectares (16 million acres), reaching 181.5 million hectares or 448 million acres around the world. Biotech crops have set a precedent in that the LMO crop area has grown impressively every single year for the past 19 years, with a remarkable 100-fold increase since the commercialization began in 1996. Thus, LMO crops are considered as the fastest adopted crop technology in the history of modern agriculture (James 2011).

The present study was undertaken to assess the socioeconomic effects of LMOs. The crops and traits were chosen as *Bt* cotton in comparison with traditional or pigeon pea because of non availability of non-GM cotton, the traditional crop of the region was taken for comparison in Hyderabad Karnataka with the following objectives:

- To assess increase in yield/productivity
- To assess the reduction in use of insecticides/pesticides
- To assess the health benefits of LMOs
- To analyze the economic gains to the farmers
- To assess the impact of seed prices on overall cost and changes in yield
- To assess the impact of LMOs on labour (men & women).

The cropping pattern is as given in Table 8.1.

8.2 Methodology

The methodology that has been followed are described below:

- Description of the study area
- Sampling procedure
- Nature and sources of the data
- Analytical techniques employed.

8.2.1 Description of the Study Area

The data collection was carried out in five districts of Hyderabad–Karnataka region namely Raichur, Koppal, Ballary, Yadigiri and Kalaburgi districts during September and October 2015. From each district based on the cropping pattern talukas and villages were selected. The different stakeholders *viz*., farmers and farm labourers depending on *Bt* cotton based farming, input dealers/traders who are engaged in seeds and pesticides business and academicians/researchers from different institutions within the study area were selected randomly for collecting the required data.

Table 8.1 Cropping pattern of sample farmers in study area

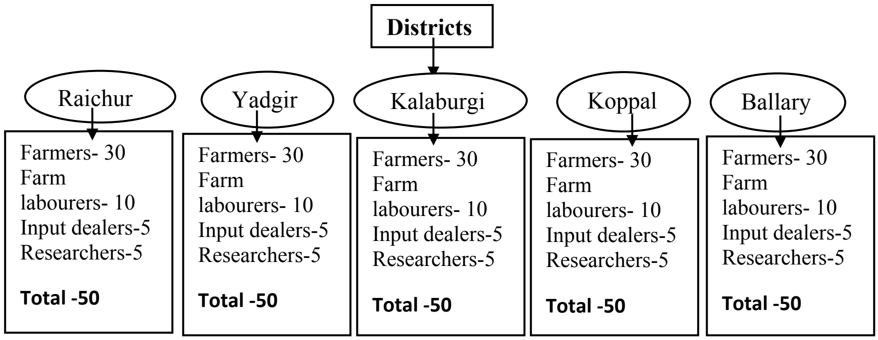
Sl. no.	Crops	Sample farmers (n = 150)			
		kharif		*Rabi/summer*	
		Average Area (acres)	% Area to total	Average Area (acres)	% to total
(A)	*Cereals*				
1	Paddy	2.83	16.35	–	–
2	Sorghum	–	–	0.73	44.00
3	Bajra	0.24	1.38	–	–
(B)	*Pulses*				
3	Pigeon pea	4.83	27.88	–	
4	Bengal gram	–	–	0.93	56.00
(C)	*Oil seeds*				
	Sunflower	0.27	1.54	–	–
	Ground nut	0.20	1.15		
(D)	*Commercial crops*				
9	Cotton	7.71	44.46	–	–
(E)	*Vegetables*				
11	Chilli	0.59	3.38	–	–
12	Brinjal	0.25	1.46	–	–
13	Onion	0.21	1.23	–	–
	Total	17.33	100.00	1.67	100.00

Source Data collected from surveys

8.2.2 Sampling Procedure

For evaluating objectives of the study, farmers cultivating *Bt* cotton and pigeon pea were selected. For the selection of farmers, a purposive multistage random sampling procedure was adopted in the study area because sampling plans where the sampling is carried out in stages using smaller and smaller sampling units at each stage. A total of 250 samples were collected which includes different stakeholders *viz*., farmers, farm labourers, traders/input dealers and academicians/researchers. The samples were divided among the different stakeholders for convenient and effective data collection as follows.

8.2.3 Distribution of Samples in the Study Area



8.2.4 Nature and Sources of Data

This study was conducted in Central and Northern Dry zone of Karnataka. The data for the study was collected from different stakeholders related to LMOs crop cultivation *viz.*, farmers, farm labourers, traders/input dealers and academicians/researchers. The source of primary data was collected through the personal interview with pre defined schedule.

8.2.5 Analytical Techniques Employed

For quantitative assessment of the objectives of the present study, following analytical tools and techniques were employed.

8.2.5.1 Tabular Analysis

Tabular analysis was used for the purpose of estimation and comparison of the economic characteristics of reference and pigeon pea cultivation followed by sample farmers *viz.*, land holding size, pattern of cropping, cost and returns and issues faced by the farmers and for analyzing data collected through opinion surveys from sample farmers. With the help of averages, data were compared and contrasted.

8.2.5.2 Functional Analysis

To study resource use efficiency in reference and pigeon pea cultivation, a modified Cobb–Douglas type of production function in log-linear form was fitted because it was most suitable for the resource use efficiency compared to that of any other production functions. This was done with a view to determine the extent to which the important resources that have been quantified, explain the variability in the output of the reference and pigeon pea cultivation and to determine whether there sources used optimally or not. In India the *Bt* cotton is the only approved and commercially released LMO by Govt. of India. Hence, we referred *Bt* cotton as reference LMO crop and traditional crop of the region i.e. Pigeon pea (because of non availability of non-*Bt* cotton in the study area) for comparison in all respects.

Cost of cultivation: It is the sum of variable costs, fixed costs and marketing cost expressed on per acre basis.
Gross returns: Gross returns were obtained by multiplying the total product with its unit value.
Net returns: Net returns were obtained by deducting the total costs incurred from the gross returns obtained.
Returns per rupee of investment: It was obtained by dividing the gross returns by cost of cultivation.

Heady and Shaw (1954) indicated that the Cobb-Douglas type of production function has been the most popular of all possible algebraic forms in the farm level data analysis as it provides comparison, adequate fit, computational feasibility and sufficient degrees of freedom. The use of Cobb–Douglas regressions estimated with aggregate data to diagnose misallocation of social resources, on the other hand, never really caught on with agricultural economists. However, inspired by the growth accounting literature that built on Solow's (1957) paper, Griliches (1963) re-introduced the aggregate Cobb-Douglas production function into the agricultural economics literature as a tool for exploring the nature of productivity growth and technological change in agriculture, a role in which it would come to be widely used.

The general form of the function is $y = ax_i^{bi}$ where, 'x_i' is the variable resource measure, 'y' is the output, 'a' is a constant and 'b_i' estimates the extent of relationship between x_i and y and when x_i is at different magnitudes. The 'b' coefficient also represents the elasticity of production in Cobb–Douglas production function analysis. Functions of the following form were fitted for conventional and Bt cotton.

$$Y = a\, x_1^{b1}\, .x_2^{b2}\, .x_3^{b3}\, .x_4^{b4}\, .x_5^{b5}\, .x_6^{b6}\, ._e^{u} \tag{3.1}$$

The Eq. (3.1) was converted into log-linear form and the parameters (coefficients) were estimated by using Ordinary Least Squares (OLS) method.

$$\begin{aligned} \log Y &= \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + b_4 \log x_4 \\ &\quad + b_5 \log x_5 + b_6 \log x_6 + U \end{aligned} \tag{3.2}$$

where

$$Y = \text{Output (quintals/acre)},\ a = \text{Intercept},\ b_i = \text{Elasticities of production}$$

X_1 Seeds (kg/acre)
X_2 Human labour (man days/acre)
X_3 Bullock and Machine labour (Rupees/acre)
X_4 Organic manures (Rupees/acre)
X_5 Inorganic fertilizers (Rupees/acre)
X_6 Plant protection chemicals (Rupees/acre)
e Error term.

8.3 Results and Analysis

8.3.1 Socioeconomic Characteristics of the Sample Farmers in the Study Area

Socioeconomic characteristics of the sample farmers and farm labourers help in providing a bird's eye view of the general features prevailing in the study area. The socioeconomic characters of the respondents are presented in Table 8.1. In case of farmers, 75.33% belonged to the average age group of 25–50 years, 13.33% belonged to the average age group of less than 25 years, while 11.33% belonged to the average age group of more than 50 years. Whereas, in the case of farm labourers, 84% were in the age group of 25–50 years, 10% were in the age group more than 50 years and 3% of them were found be in the age group of less than 25 years (Figs. 8.1 and 8.2). It could be further observed that 76.67% of the sample farmers and 50% farm labourers are having a farming experience of 10–30 years, 14% sample farmers and 34% farm labourers are having a farming experience of less than 10 years and only 9.33% of the farmers and 16% of the farm labourers are having a farming experience of more than 30 years. With respect to LMO crop cultivation, i.e. Bt cotton, 70% of the sample farmers and 54% of the farm labourers are having less than 5 years experience, 30% of the farmers and 46% of the farm labourers are having a experience of 5–8 years and none of the farmer and farm labourer had more than 8 years experience in LMO cultivation.

From the Table 8.2, it could be seen that 56.67% of sample farmers and 48% farm labourers were illiterate. 43.33% of farmers and 52% of farm labourers were found to be literates and literates having their education ranging from primary to college level. The average family size in the case of farmers was seven members and in case of farm labourers it was four members, main reason behind this is a nuclear family. The average income of the family in case of farmers was found to be Rs. 59340 per annum (Rs. 46130 form agriculture and Rs. 13210 from other sources) and in case of

Fig. 8.1 Map showing study area

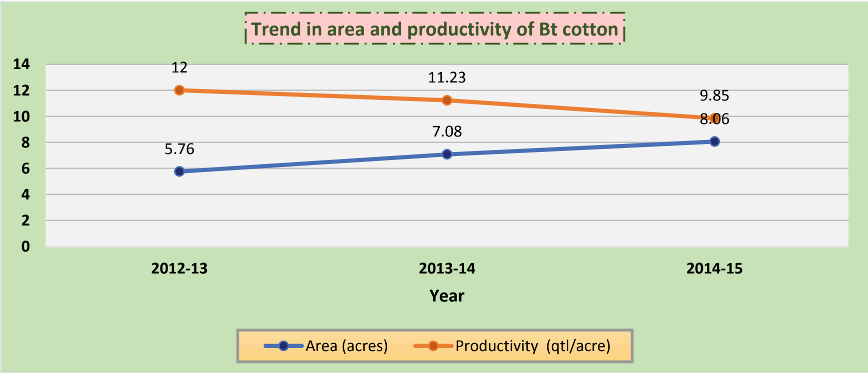


Fig. 8.2 Trend in area and productivity of Bt cotton

farm labourers it was Rs. 20690 (Rs. 16230 form agriculture and Rs. 4460 from other sources). Average landholding of sample farmers in study area was 21.03 acres, of which 12.31 acres was rainfed and 8.72 acres was found to be irrigated.

8.3.2 Pattern and Extent of Input Usage by Sample Farmers in the Study Area

Comparative input use pattern between Bt cotton, non-Bt cotton and pigeon pea are presented in Table 8.3. In Bt cotton among all the inputs, on an average the farmers have incurred high cost for purchase of inorganic fertilizers (Rs. 3830.30) followed by cost on seeds (Rs. 1914.00), plant protection chemicals (Rs.1732.50) and lowest cost was incurred was on organic manures (Rs. 392.60). Whereas in case non-Bt cotton on an average the farmers have incurred high cost for plant protection chemicals (Rs. 2222.50), purchase of inorganic fertilizers (Rs. 1679.63) followed by on seeds (Rs. 336.96) and lowest cost was incurred was on organic manures (Rs. 208.00). In case of pigeon pea also higher cost incurred on inorganic fertilizers (Rs. 2926.89) followed by on plant protection chemicals (Rs. 1959.40), seeds (Rs. 399) and organic manures (Rs. 310.30). From the Table 8.3 it could be seen that, in both the crops inorganic fertilizers and plant protection chemicals add more costs to cultivation than other inputs. In addition to these seed component also adds considerable costs in Bt cotton.

Table 8.2 Socioeconomic characteristics of the sample respondents

Sl. no.	Particulars	Unit	Farmers (n = 150)	Farm labourers (n = 50)
1.	Age	<25 yrs	20 (13.33)	3 (6.00)
		25–50 yrs	113 (75.33)	42 (84.00)
		>50 yrs	17 (11.33)	5 (10.00)
2.	Experience in farming	<10 yrs	21 (14.00)	17 (34.00)
		10–30 yrs	115 (76.67)	25 (50.00)
		>30 yrs	14 (9.33)	8 (16.00)
3.	Experience in LMO crop cultivation	<5 yrs	105 (70.00)	27 (54.00)
		5–8 yrs	45 (30.00)	23 (46.00)
		>8 yrs	–	–
5.	Education Level (Nos.)			
	Illiterate	No.	85 (56.67)	24 (48.00)
	Primary	No.	24 (16.00)	12 (24.00)
	High school	No.	23 (15.33)	14 (28.00)
	College/degree	No.	18 (12.00)	–
6.	Average Size of the family	No.	7	4
7.	Average annual income of the family			
	Agriculture & allied activities	Rs.	46130	16230
	Other sources	Rs.	13210	4460
	Total	Rs.	59340	20690
8.	Average Landholdings			
	Irrigated	Acres	8.72	–
	Rainfed	Acres	12.31	–
	Total	Acres	21.03	–

Source Data collected from surveys
Note Figures in parenthesis indicate percentage to the total

Table 8.3 Input use pattern of sample farmers in the study area (kg./acre)

Sl. no.	Particulars	Bt cotton (n = 150)	Value in Rs.	No-Bt cotton	Value in Rs.	Pigeon pea (n = 150)	Value in Rs.
1.	Seeds	0.970	1914.00	1.56	336.96	4.62	399.90
2.	Organic manures	634.83	392.60	320.00	208.00	506.54	310.30
3.	Inorganic fertilizers						
	Urea	125.60	887.20	81.25	438.75	47.53	380.24
	DAP	103.90	2559.60	31.25	750.00	90.50	2311.20
	Potash	26.86	383.50	26.25	490.88	15.70	235.45
4.	Plant protection chemicals	–	1732.50	–	2222.50	–	1959.40
Total		–	7869.40	–	4447.09	–	5586.19

Source Data collected from surveys

*8.3.3 Labour Use Pattern in Bt Cotton, Pigeon Pea and Non-*Bt *Cotton Crop*

Labour use pattern in the cultivation of Bt cotton, pigeon pea and non-*Bt* cotton crop are presented in the Table 8.4. It is evident from the table that on an average, the farmers engaged more human (56.21 man days) in cultivation of Bt cotton crop followed by non-*Bt* cotton crop (49.48 man days) and pigeon pea (25.23 man days).

Further the data indicates that, Bt cotton farmers have engaged human labour for the operations like harvesting and transportation (20.5 man days), irrigation (5.76 man days), PPCs spraying (5.39 man days), fertilizers applications (4.73 man days), inter-cultivation (4 man days), sowing (4.27 man days) and lowest human labour was engaged for land preparation (2.5 man days). Form the table it is clear that Bt cotton crop cultivation generates more employment opportunities for both men (28.30 man days) and women labour (27.91 man days) compared to non-Bt cotton crop (24.04 man days) and women (26.44) labour and pigeon pea (15.91 & 9.32 man days).

In Table 8.4 represents the labour use pattern of bullock and machinery. The cultivation of Bt cotton requires more bullock labour (4.60 pair days) followed by non-Bt cotton crop (3.85 pair days) and pigeon pea (3.65 pair days), this might be attributed to the taking of additional operations in Bt cotton *viz*., marking of lines for sowing and inter cultivations. On an average usage of machinery labour was more in pigeon pea (4.49 h) than the Bt cotton crop (2.96 h) and non-Bt cotton (1.25 h). In pigeon pea harvesting and threshing operation in addition to land preparation is done by machineries and hence machine labour requirement is more in pigeon pea than in Bt cotton and non-Bt cotton crop.

On the whole the Bt cotton crop cultivation generated more employment opportunities than the pigeon pea and non-Bt cotton crop.

Table 8.4 Labour use pattern in Bt cotton, non-Bt cotton and Pigeon pea cultivation in the study area (Per acre)

Operations	Human labour (man days)								
	Bt cotton			Non-*Bt* cotton crop			Pigeon pea		
	Men	Women[a]	Total human labour	Men	Women[a]	Total human labour	Men	Women[a]	Total human labour
Land preparation	2.50	–	2.5	2.00	–	2.00	2.30	–	2.3
Sowing	0.46	3.81	4.27	3.14	1.00	4.14	0.41	1.48	1.89
Fertilizer application	3.53	1.20	4.73	3.00	1.66	4.66	1.68	0.83	2.51
Hand weeding	1.03	8.03	9.06	1.50	7.2	8.70	0.56	2.78	3.34
Inter cultivation	4.00	–	4	3.00	–	3.00	1.84	–	1.84
Spraying PPC's	5.39	–	5.39	5.00	2.25	7.25	6.27	–	6.27
Irrigation	5.76	–	5.76	3.4	–	3.40	–	–	–
Harvesting and transportation	5.63	14.87	20.5	3.00	13.33	16.33	2.85	4.23	7.08
Total	28.30	27.91	56.21	24.04	26.44	49.48	15.91	9.32	25.23

Source Data collected from surveys
Note women days are converted into man equivalent days based on wage rate. (this data of non-bt cotton pertains to only research station not the farmers data)

8.3.4 *Trend in Area and Productivity of Bt Cotton in the Study Area*

The trend of Bt cotton cultivation in the study area is presented in Table 8.5. The area under Bt cotton crop in the study area has shown increasing trend (from 5.67 to 8.06 acres per farmer) and productivity has shown gradual decreasing trend (from 12 to 9.85 qt per acre) over the years. The increasing area under Bt cotton in the study area might be due to the availability of high-quality seeds, good marketing facility, bollworm resistant and high yielding hybrids and also because of assured income. The decline in the productivity of Bt cotton crop in the study area may be attributed to water stress, prevalence of sucking pests, flower drop and leaf reddening problems (Fig. 8.2) (Table 8.6).

Table 8.5 Labour use pattern in Bt cotton, non-Bt cotton and Pigeon pea cultivation in the study area (Per acre)

Operations	Bullock labour (pair days)			Machine labour (hrs)		
	Bt cotton	Non-*Bt* crop	Pigeon pea	Bt cotton	Non-*Bt* crop	Pigeon pea
Land preparation	1.27	1.00	1.13	2.96	1.25	2.56
Sowing	1.10	1.00	0.92	–	–	–
Fertilizer application	–	–	–	–	–	–
Hand weeding	–	–	–	–	–	–
Inter cultivation	2.23	1.85	1.60	–	–	–
Spraying PPC's	–	–	–	–	–	–
Irrigation	–	–	–	–	–	–
Harvesting and transportation	–	–	–	–	–	1.93
Total	4.60	3.85	3.65	2.96	1.25	4.49

Source Data collected from surveys

Table 8.6 Trend in area and productivity of Bt cotton in the study area

Year	Area (acres)	% change over previous year	Productivity (qtl/acre)	% change over previous year
2012–13	5.76	–	12.00	–
2013–14	7.08	22.92	11.23	−6.42
2014–15	8.06	13.84	9.85	−12.29

Source Data collected from surveys
Note There is no information on non-Bt cotton hybrid productivity trend

8.3.5 *Use of Seed, Plant Protection Measures and Bt Cotton Cultivation*

Table 8.7 depictsthe details of quantity of seeds used for cultivation of Bt cotton. On average farmers used 0.977 kg of seed per acre with an average price of Rs. 1958.54 per kg of seed. All the farmers were (100%) depending on purchased seeds for the cultivation of Bt cotton and none of the farmers were found to use own seeds (because of Bt). Most of the farmers purchased seeds on credit basis (65.33%) and 34. 67% farmers purchased seeds on cash. While purchasing the seeds only 27.33% of farmers got technical advice from input dealer and rest of them (72.67%) did not get proper advice from the same source. It is evident that, about 94.66% of the farmers responded positively towards the quality of the seeds i.e. germination quality and only 5.33% responded negatively.

8.3.5.1 Plant Protection Measures in Bt Cotton

The details of plant protection measuresin Bt cotton in shown in Table 8.8. In case of cultural method for control of insect pest human labour (Rs. 1600.00) is higher and there is no need of machinery and bullock pair followed by weeds, Rs. 1056.50 for human labour. Similarly, in case of disease/disorder only human labour is required (Rs. 600.00). Cost involved in control of insect pest Rs. was higher i.e. 1600.00 followed by and weeds Rs. 1056.50 and disease/disorder Rs. 600.00.

Tables 8.8 and 8.9 depict the plant protection measuresin Bt cotton through chemical methods. None of the farmer practiced chemical method for control of weeds in Bt cotton. In case of insect pests management chemical method was more popular, on an average 54% of the farmers used less than 3 sprays, 39.3% of farmers used 3–4 sprays and only 6.66% used more than 4 sprays of chemicals to control

Table 8.7 Details of quantity of seed used for Bt cotton Bt cotton crop cultivation

Sl. no.	Particulars		No.	Percent
1	Quantity of seed used (0.977 kg)		150	100.00
2	Price paid Rs. 1958.54/kg		150	100.00
3	Source of seed	(a) own	–	–
		(b) purchase	150	100.00
4	Type of purchase of seed	(a) Credit	98	65.33
		(b) Cash	52	34.67
5	Technical advice provided by the seed seller		41	27.33
6	Opinion on germination quality of the seed	(a) High	142	92.66
		(b) Low	8	5.33

Source Data collected from surveys
Note Figures in parenthesis indicate percentage to total numbers of samples

Table 8.8 Details of plant protection measures in Bt cotton (Rs./acre)

Particulars	Cultural methods (n = 150)			
	Machinery cost	Bullock pair cost	Human labour cost	Total cost
Weeds	–	–	1056.50	1056.50
Insect pests	–	–	1600.00	1600.00
Diseases/ disorders	–	–	600.00	600.00

Source Data collected from surveys

Table 8.9 Details of plant protection measures plant protection measures in Bt cotton crop (Per acre)

			Weeds	Insect pests	Diseases/disorders
Chemical methods (n = 150)	Nature of chemical (in Percent)	Systemic	–	67	52
		Contact	–	33	48
	No. of sprays	<3	–	81 (54.00)	112 (74.67)
		3–4	–	59 (39.30)	33 (22.00)
		>4	–	10 (6.67)	5 (3.33)
	Qty used (kg)		–	1.05	0.25
	Value in Rs		–	1386.2	544
	Machinery charge (Rs.)		–	528.00	430
	Human labour charge (Rs.)		–	1931.00	1294
	Total cost (Rs.)			3845.20	2268

Source Data collected from surveys
Note Figures in parenthesis indicate percentage to total numbers of samples

insect pests. The total cost involved to control insect pest through chemical method was Rs. 3845.20. For control of disease/disorders in Bt cotton, farmers used about 52% systemic and 48% contact insecticides. On an average 74.67% of the farmers used less than 3 sprays, 33% used 3–4 sprays and only 3.33% of farmers used more than 4 sprays to control diseases/disorders. The total cost involved to control diseases/disorders through the chemical method was Rs. 2268.00. Among plant protection measures in Bt cotton the total cost through chemical measures to control insect pests (Rs. 3845.20) was higher than diseases/disorders (Rs. 2268.00).

Table 8.10 Perception and Practice of farm labourers and farmers about spraying of PPCs (n = 200)

Sl. no.	Particulars	No.	Percent
1	Use of protective cloths, boots and spectacles while applying PPCs	60	30.00
2	Following of wind direction while spraying	146	73.00
3	Eating/drinking water/smoking while spraying	–	
4	Proper hand wash after spray	136	68.00
5	Training regarding the usage of PPCs	58	29.00
6	Dosage of PPCs usage		
	(a) Recommended	61	30.50
	(b) More than recommended	121	60.50
	(c) Less than recommended	18	9.00

Source Data collected from surveys

8.3.5.2 Plant Protection Measures Farm Labourers and Farmers Perspective

Table 8.10 depicts the details of Plant Protection Chemicals (PPCs) spraying methods from farm labourers and farmer's perspective, i.e. their perceptions and practices. It indicates that majority of the sample farmers and farm labourers (70%) were not using any protective clothes, boots and spectacles while spraying PPCs. About 73% of the respondents were following right wind direction while spraying and none of the respondents were found to eat/drink/smoke while spraying PPCs. Only 68% of the respondents wash their hands properly after PPCs spraying and 85.6% of the respondents were not received any training regarding the proper usage of PPCs.

From the table it is clear that about 60.05% of the respondents were using more than the recommended dosage of PPCs, 9% were using less than recommended dosage of PPCs and only 30.50% of respondents were using recommended dosage of PPCs.

8.4 Comparative Cost of Cultivation of Bt Cotton, Pigeon Pea and Non-Bt Cotton Crop

The comparative cost of cultivation of Bt cotton, Pigeon pea and non-Bt cotton crop are presented in Table 8.11 Among the variable cost, expenditure on human labour was found to be highest in Bt cotton which was Rs. 12842.00 followed by fertilizers and organic manures (Rs. 4162.87), seeds (Rs. 1914.10), bullock labour (Rs. 1798), PPCs (Rs. 1732.50). Whereas, in case of Pigeon pea the expenditure on human labour was found to be highest (Rs. 5307.50) followed by fertilizers and organic manures (Rs. 2351.66), PPCs (Rs. 1959.40), bullock labour (Rs. 1349), machine labour (Rs.

Table 8.11 Comparative cost of cultivation of Bt cotton, non-*Bt* cotton and Pigeon pea (Rs./acre)

Sl. no.	Particulars	*Bt* cotton	Non-*Bt* cotton	% *Bt* cotton over Non-*Bt* cotton	Pigeon pea
A.	*Variable costs*				
1.	Land preparation	1315.00	1500.00	−12.33	1043.43
2.	Seeds	1914.10	336.96	468.05	399.90
3.	Fertilizers and organic manures	4162.87	1636.80	154.33	2351.66
4.	Pesticides/insecticides	1732.50	2222.50	−22.05	1959.40
5.	Human labour	12842.00	12370.00	3.82	5307.50
6.	Bullock labour	1798.00	1155.00	55.67	1349.00
7.	Machine labour	980.00	1125.00	−12.89	1347.00
8.	Interest on working capital @ 3%	742.33	698.07	6.34	412.74
	Sub total	25486.80	21044.33	21.11	14170.63
B.	*Fixed costs*				
1.	Land revenue	50.00	50.00	−3.79	50.00
2.	Rental value of land	5580.00	5800.00	−1.76	4190.00
3.	Depreciation	835.00	850.00	12.41	850.00
4.	Interest on fixed capital @ 11.5%	829.73	738.15	−3.20	831.45
	Sub total	7208.48	7447.15	14.75	5675.35
C.	Total cost of cultivation (A + B)	32695.28	28491.48	−3.79	19845.98

1347) and relatively less expenditure on seeds (Rs. 399.90). Similarly in case of non-Bt cotton crop highest expenditure incurred by human labour (Rs. 12370) followed by PPCs (Rs. 2222.50), fertilizers and organic manures (Rs. 1636.80), land preparation (Rs. 1500), bullock labour (Rs. 1155), machine labour (Rs. 1125). However, overall variable cost was high in Bt cotton crop (Rs. 25486.80) as compared to non-Bt cotton crop (Rs. 21044.33) and Pigeon pea (Rs. 14170.63).

It is revealed that human labour utilization found to be higher in Bt cotton as compared to non-Bt cotton crop and Pigeon pea, this was mainly because weeding operation was carried out for 2–3 times and harvesting operation was also carried for 5–6 times which added additional cost to the cultivation of Bt cotton. Total cost of cultivation was high in case of Bt cotton crop (Rs. 32695.28) as compared to and non-Bt cotton crop (Rs. 28491.48) and Pigeon pea (Rs. 19845.98).

8.4.1 *Costs and Returns of Bt Cotton, Pigeon Pea and Non-Bt Cotton Crop*

The details of costs and returns structure of Bt cotton, Pigeon pea and non-Bt cotton were depicted in Table 8.12 and in Fig. 8.3. It is clearly indicated that the average yield was found to be 11.23 qtl. per acre whereas in case of Pigeon pea it was 4.47 qtl. per acre and in non-Bt cotton crop yield was 7.50 qtl. per acre. On the other hand, the average price per qtl. received was Rs. 4020.33 in Bt cotton, Rs.5180.25 for Pigeon pea and Rs. 4500 price received by the non-Bt cotton farmers. Hence gross returns obtained were found to be Rs. 45148.30 per acre, Rs. 23312.25 per acre and Rs. 33750 from Bt cotton, conventional and non-Bt cotton crops respectively. The cost of cultivation was considerably higher in case of Bt cotton which was Rs. 32695.28 per acre as compared to Pigeon pea (Rs. 19845.98 per acre) and non-Bt cotton crop

Table 8.12 Costs and returns of Bt cotton, non- Bt cotton and Pigeon pea

Sl. no.	Particulars	Bt cotton	Non-*Bt* cotton	% *Bt* cotton over Non-*Bt* cotton	Pigeon pea
1.	Total cost (Rs/acre)	32695.28	28491.48	14.75	19845.98
2.	Average yield (q/acre)	11.23	7.50	49.73	4.47
3.	Average price (Rs./q)	4020.33	4500.00	−10.66	5180.25
4.	Gross returns (Rs./acre)	45148.30	337.50	33.77	23312.25
5.	Net returns (Rs./acre)	12453.05	5258.52	136.82	3466.27
6.	Returns per rupee spent	1.38	1.18	–	1.17

Source Data collected from surveys

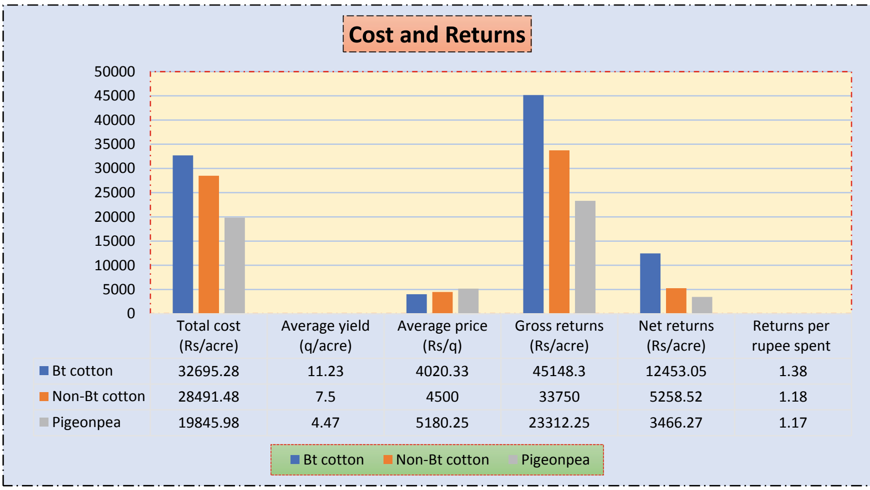


Fig. 8.3 Cost and returns of Bt cotton, non-Bt cotton and Pigeon pea

(Rs. 28491.48) these was mainly due to utilization of inputs *viz.*, human labour and chemical fertilizers was higher in Bt cotton compared to other crops. Net returns obtained to be higher in case of Bt cotton crop (Rs. 12453.05) as compared to Pigeon pea (Rs.3466.27 per acre) and non-Bt cotton crop (Rs. 5258.52). Returns per rupee of investment was high in case of Bt cotton crop (1.38) compared to Pigeon pea (1.17) and non-Bt cotton crop (1.18).

8.4.2 Production Function Estimates in Bt Cotton Cultivation

The details of production function estimatesin Bt cotton crop cultivation are presented in 8.13. As indicated in the table, the coefficients of determinations (R^2) were 0.79 indicating that the variables included in the function had explained 79% of variation in the output of Bt cotton crop.

It is worth to note that seeds, inorganic fertilizers, plant protection chemicals and human labours had significant influence on the output of Bt cotton cultivation. The output elasticity of seeds (1.371), inorganic fertilizers (0.0870), plant protection chemicals (0.0404) and human labours (0.0104) were significant in production of Bt cotton. Whereas, output elasticities of organic manure (0.268), bullock and machine labour (0.014) were non-significant. The estimated returns to scale was 1.79 it indicates the increasing rate of returns to scale (Table 8.13).

8.5 Economic Benefits and Cultivation of Cotton

Table 8.14 depicts the economic gains for the farmers from the cultivation of Bt cotton. The gross returns from the cultivation of Bt cotton was Rs. 45148.30 higher as compared to non-Bt cotton (Rs. 33750.00). The per cent change Bt cotton over non-Bt cotton was 14.75%. Similarly, the net returns gain from Bt cotton was Rs. 12453.05 higher as compared to non-Bt cotton (Rs. 5258.52). The employment of human labour marginally higher as compare to non-Bt cotton, there is 3.82% change Bt cotton over non-Bt cotton. Whereas employment of bullock pair and machine hours higher in case of Bt cotton (Rs. 2778.00) as compared to non-Bt cotton (Rs. 2280.00).

8.5.1 Incidence of Weeds, Pests and Diseases in Bt Cotton

The incidence of weed, pest and disease details of Bt cotton in study area is presented in Table 8.15. The farmers opined that weeds and insect pests occur in every season but with regard to diseases/disorders about 54% of the farmers noticed occurrence in every season and 46% of the farmers noticed incidence once in a year. In case of

Table 8.13 Regression coefficients of Bt cotton (Rs./acre)

Sl. no.	Particulars	Parameters	Coefficients
1.	Intercept	A	2.046 (0.984)
2.	Seeds	X_1	1.371* (0.900)
3.	Organic manure	X_2	0.268^{NS} (0.067)
4.	Inorganic fertilizers	X_3	0.0870** (0.011)
5.	PPCs	X_4	0.0404* (0.011)
6.	Human labour per acre	X_5	0.0104* (0.033)
7.	Bullock and machine labour	X_6	0.014^{NS} (0.021)
8.	R Square	–	0.79
9.	*F* value	–	16.279
10	$\sum$ bi	–	1.79

Source Data collected from surveys
Note Figures in the parenthesis indicate standard error of respective coefficients
*Significant at 10% level
**Significant at 5% level
NS Non-significant

Table 8.14 Economic benefit due to cultivation of cotton (Rs./acre)

Sl. no.	Particulars	Bt cotton	Non-Bt cotton	% change Bt cotton over non-Bt cotton
1.	Cost of cultivation	32695.28	28491.48	14.75
2.	Gross returns	45148.30	33750.00	33.77
3.	Net returns	12453.05	5258.52	136.82
4.	Employment of human labour	12842.00	12370.00	3.82
5.	Employment of bullock pair and machine hours	2778.00	2280.00	21.84

Source Data collected from surveys

insect pests 74% of respondent farmers noticed high severity. About 51.33% sample farmers experienced lower severity. With respect to the stage of incidence of insect pests, about 26% of farmers noticed in vegetative stage, 11.33% in flowering stage and 64% farmers in both the stages. Whereas in case of disease/disorders, about 17.33% of the sample farmers noticed incidence in vegetative stage, 38.67% in flowering stage and 44% of the farmers noticed in both the stages. The average estimated yield

Table 8.15 Perception of farmers about incidence of pests and diseases in Bt cotton Bt cotton cultivation

Sl. no.	Particulars		Weeds	Insect pests	Diseases/disorders
1	Frequency of incidence	Every season	150 (100.00)	150 (100.00)	81 (54.00)
		Once in a year	–	–	69 (46.00)
2	Severity of incidence	Low	15 (10.00)	–	77 (51.33)
		Medium	58 (38.67)	39 (26.00)	63 (42.00)
		High	79 (52.67)	111 (74.00)	10 (6.67)
3	Stage of crop growth	Vegetative period	38 (25.33)	39 (26.00)	26 (17.3)
		Flowering period	14 (9.33)	17 (11.33)	58 (38.67)
		Both the periods	98 (65.33)	96 (64.00)	66 (44.00)
4	Estimated yield loss (%)		21.6	25.94	15.33

Source Data collected from surveys

loss was higher from the insect pests which were about 25.94% followed by weeds (21.60%) and disease/disorders (15.33%) respectively.

8.6 Farmers' Perception About LMOs

Table 8.16 depicts the farmers perception about LMOs and it is clear that about 92.67% of the farmers have shown tendency towards acceptance of new variety of LMOs with desired traits. Only 7.33% of the respondents negatively responded in acceptance of new variety of LMOs.

Among the farmers who have shown the positive attitude towards acceptance of LMOs was about 68.67% were willing to pay more than 50, 12% of the farmers were willing to pay 25–50, 10.66% of the farmers were willing to pay 10–25%. With regard to price fixation for the output of LMO crop, about 66.67% of the farmers opined that price should be 2 times more than non LMO crop, 24% of the farmers opined that price should be 1.5 times more and 9.33% of the farmers opined that price of LMO crop output should be more than 1.25 times than output of non LMO crop.

With respect to market information for marketing of LMO crop output, about 90.67% of the sample farmers seeking information about market prices before planting, 52% of the farmers seeking information about market Bt cotton before planning LMOs. Among the respondent farmers about 59.33% did not have knowledge about LMOs and 62% of the farmers did not have proper information regarding the cultivation of LMOs crop.

Table 8.16 Farmers' perception about LMOs Farmers' perception about LMOs

Sl. no.	Particulars		Nos.	Percent
1	Do you accept new variety of LMOs with desired traits		139	92.67
2	Willingness to pay for the seeds of LMOs crop with desired trait	<10% of the price paid last season	13	8.67
		10–25% of the price paid last season	16	10.66
		25–50% of the price paid last season	18	12.00
		>50% of the price paid last season	103	68.67
3	What price should be fixed for LMO crop output with desired trait	Same as that of existing crop	–	–
		1.25 times more	14	9.3
		1.5 times more	36	24.00
		2 times more	100	66.67
4	Seeking information about market prices before planting LMOs		136	90.67
5	Seeking information about market Bt cotton before planting LMOs		78	52.00
6	Knowledge about LMOs		61	40.67
7	Training/information regarding the LMOs crop cultivation		57	38.00

Source Data collected from surveys

8.6.1 Knowledge About LMOs Among the Different Stakeholders

Table 8.17 depicts that among the different stakeholders, academicians/researchers were having 100% knowledge about GMO crops followed by input dealers/traders (70%), whereas farmers (42%) and very less number of farm labourer had knowledge about the GMO crops. The academicians/researchers (100%) believed that GM cotton gives higher yield compared to other hybrids, whereas 93.33% of dealers/traders, 75.33% of farmers and 74% of farm labourers stated that GM cotton gives higher yield than other hybrids.

Among the different samples about 96.67% of farmers, 64% of farm labourers, cent percent of input dealers/traders and 75% of the academicians/researchers responded that, GM cotton needs higher inputs than that of other cotton hybrids. From the study it is clear that 100% of academicians/researchers and input dealers/traders, 98% of the farmers are interested in cultivation of new variety of LMO with desired trait. The opinion on harmful effects of GM crop cultivation varied among the different stakeholders. About 34% of the farm labourers, 10% of the farm labourers and 16.67% of the input dealers/traders stated that GM crop cultivation is harmful to human and livestock. None of the academicians/researchers have stated any kind of harmful effects of GM crop cultivation on human, livestock and environment.

Table 8.17 Knowledge and perception about LMOs among the different stakeholders

Sl. no.	Particulars	Farmers (n = 150)		Farm labourers (n = 50)		Input dealers/traders (n = 25)		Academicians/researchers (n = 25)	
		No.	%	No.	%	No.	%	No.	%
1	Knowledge about genetic modification of crops	63	42.00	15	30.00	21	84.00	25	100.00
2	GM crops cultivation led to increase in profit	137	91.33	37	74.00	23	92.00	25	100.00
3	GM cotton crops need higher inputs	145	96.67	32	64.00	25	100.00	19	76.00
4	Willingness to go for new LMO variety with desired trait	147	98.00	–	–	25	100.00	25	100.00
5	GM crop harmful to human and livestock	15	10.00	17	34.00	4	16.00	–	–

Source Data collected from surveys

8.6.2 Risk Perception About LMOs (from Academicians/Researchers Perspective)

Table 8.18 represents the risk perception about LMOs (From academicians/researchers perspective). 100% of academicians/researchers were found to strongly agree that GM crops like *Bt* cotton will be beneficial for farmers. Majority of academicians/researchers strongly agree (65.00%) that adoption of GM seeds will reduce the cost of cultivation, whereas 15% were somewhat agree and 20% of them disagree with the statement. 75% of academicians/researchers strongly agree that cultivation of GM crops will ensure food security for the rapidly growing population. Whereas 15% somewhat agree and 10 were disagree with the statement.

65% of the academicians/researchers agree that cultivation of GM crops will be risky as pollen flow from GM plants will contaminate other neighbouring crops. Whereas, 35% of them strongly disagree with the statement. All the interacted academicians/researchers were strongly disagree with statement that GM crops will cause harm to human and cattle. With respect to health risks from GM foods about 90% of academicians/researchers disagree and only 10% were agreeing with statement. 35% of academicians/researchers have a perception that cultivation of GM crops will harm agro- biodiversity and rest of them did not agree with statement. All the interacted academicians/researchers agreed to the statement that, the production and trade of GM seeds will increase the monopoly of big companies in the seed market. The majority of the interacted academicians/researchers agreed that rigorous testing is done for worthiness of bio safety before release of GM crops, the scientists involved in genetic engineering research do not conceal the data about harmful effects of GMOs and both small and large farmers benefitted from the GM technology. All the academicians/researchers suggest that, the GM foods should be labelled for the benefit of consumers.

8.7 Conclusion

The study clearly indicated that LMO crop provides more employment opportunity for both the labourers as compared to pigeon pea and non-Bt cotton crop. It was observed that the area under LMO crop had higher yield productivity of crop over the period. The application of plant protection chemicals was relatively higher in case of non-Bt cotton as compared to Bt cotton. In case of Bt Cotton, the net returns accrued were higher (Rs. 12453.05), which was mainly due to higher level of yield. The Return on Investment (ROI) was found to be higher in the case of Bt cotton (1.38) as compared to Pigeon pea (1.17) and non-Bt cotton crop (1.18). They have showed favourable inclination towards the LMOs and they are ready to accept if *Bt* crops are brought as pigeon pea provided it should be scientifically proved without harming the livestock.

Table 8.18 Perception of researchers/academicians about risk involved in cultivation Bt cotton (n = 25)

Sl. no.	Statements	Strongly agree	Agree	Somewhat agree	Disagree	Strongly disagree
1	GM crops like *Bt* cotton is beneficial for farmers	25 (100.00)	–	–	–	–
2	Adoption of GM crops will help in reducing the cost of cultivation	16 (64.00)	–	4 (16.00)	5 (20.00)	–
3	Cultivation of GM crops will ensure food security for the rapidly growing population	17 (68.00)	3 (12.00)	5 (20.00)	–	–
4	Cultivation of GM crops will be risky as pollen flow from GM plants will contaminate other neighbouring crops	–	7 (28.00)	10 (40.00)	3 (12.00)	5 (20.00)
5	GM crops carry genes from different species hence they are harmful to the human beings	–	–	–	–	25 (100.00)
6	Entry of GM food in food chain will cause health risk	–	–	2 (8.00)	5 (20.00)	18 (72.00)

(continued)

Table 8.18 (continued)

Sl. no.	Statements	Strongly agree	Agree	Somewhat agree	Disagree	Strongly disagree
7	Cultivation of GM crops will harm agro-biodiversity	–	9 (36.00)	6 (24.00)	6 (24.00)	4 (16.00)
8	The production and trade of GM seeds will increase the monopoly of big companies in the seed market	7 (28.00)	13 (52.00)	5 (20.00)	–	–
9	Rigorous scientific testing is done prior to release of GM crops	22 (88.00)	3 (12.00)	–	–	–
10	Genetic engineering scientists tend to conceal data about harmful effects of GMOs	–	–	–	4 (16.00)	21 (84.00)
11	Only the large farmers will be benefitted by genetic engineering technology	–	–	6 (14.00)	6 (24.00)	13 (52.00)
12	Genetically modified foods should be labelled for the benefit of consumers	25 (100.00)	–	–	–	–

(continued)

Table 8.18 (continued)

Sl. no.	Statements	Strongly agree	Agree	Somewhat agree	Disagree	Strongly disagree
13	Deployment of GM crops will rise the cost of cultivation	3 (12.00)	10 (40.00)	3 (12.00)	5 (20.00)	4 (16.00)
14	Prevalence of secondary pests will increase	15 (60.00)	4 (16.00)	6 (24.00)	–	–

Source Data collected from surveys
Note Figures in parenthesis indicate percent of respondents

8.7.1 Suggestions/Recommendations

(1) There is a need to conduct more number of trainings and programmes to create awareness about LMOs/GMOs, their cultivation practices and also about importance of refugee crop among the farmers to enable them to harness the full potential of GM technology.
(2) The Government may encourage the extension of GM technology to the more crops like pulses especially the pigeon pea, where the pod borer incidence is the major constraint which is hindering the production and also encourage PPPs in GM technology, so that our farmers will be benefited from competition and faster commercialization.
(3) Further the Government may undertake some measures to reduce the price of GM crop seeds which finally leads to reduce the cost of cultivation of GM crops.
(4) As per the recommended Seed rate (RDF), the seed package may be prepared 750 g.

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Chapter 9
Adoption and Impact of Brinjal and Maize Living Modified Organisms (LMOs) in Telangana

K. Srinivas, P. C. Meena and Subash Surendran Padmaja

Abstract This chapter deals with methods and application for assessment of adoption and impact of Living Modified Organisms. A detailed review of studies carried out in this regard and outline of data and methods are provided. To demonstrate the application of these methods an ex ante study on adoption and impact of genetically modified brinjal and maize was carried out in Nalgonda district of Telangana state in India. Total of 250 households (125 each for brinjal and maize) were sampled and surveyed. The chapters detail the socio-economic and farm characteristics of the farmers. The study showed that farmers were interested in alternative crop varieties (HYV, Hybrid or LMOs) which could have tolerance and resistance against abiotic and biotic stresses. About 58.4% of the brinjal farmers and 76% of the maize farmers expressed their interest in adoption of crop with such trait. The cost of inputs to manage the pest (in brinjal) and weeds (in maize) were found to be key factors influencing adoption. The farmers stated that they were willing to pay more (>10%) for the seed of the new LMO variety. The study based on benefit–cost ratio scenario shows even in such scenario the crop would be still economically viable for farmer.

Keywords LMO · Bt brinjal · Telangana · HYV · Hybrid · Maize

9.1 Introduction

The Article 26 of the Cartagena Protocol on Biosafety (CPB) envisages to protect the right of Parties by taking into account socio-economic considerations arising from the transboundary movement and its impact of LMOs on the conservation and sustainable use of biodiversity. This component will also allow the biosafety regulatory system to address concerns raised from time-to-time by various stakeholders on socio-economic impact of LMOs for agriculture.

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The evolving international norms and practice in incorporating socio-economic aspects in decision making on LMOs is need to develop a framework in the country. This chapter explores methodologies and results from socio-economic (SE) assessment of Maize and Brinjal (one trait each for which LMOs are available) and find the perception of the farmers for socio-economic assessment for allowing the LMOs in the national system. The study was undertaken as part of a project to develop an integrated framework of regulating LMOs.

9.2 Socio-Economic Assessment: Review of Data and Methods

There are various approaches, methods and techniques which could be used for socio-economic assessments. A review of 27 studies where done to understand the various socio-economic assessment methods. Most of the studies chosen for review where done in India so that the socio-economic assessment methodologies would be suitable to India. In addition to that few reviews where done in both GM crops (other than India) and non-GM crops to explain other methods. The reviews were purposively selected to explain different methodologies.

9.2.1 Approaches, Methods and Techniques

Three approaches/methods could be applied for LMO socio-economic assessment. A summary of various methods approaches and techniques are provided in Table 9.1.

Table 9.1 Framework for socio-economic assessment

	Approaches	Ex-ante	Ex-post
Micro	Adoption	Simulation	Logit/probit, tobit, heckman, double hurdle
	Impact	Simulation, Ex-ante economic surplus analysis	Randomized Control Trail (RCT), PSM (Propensity Score Matching), DD (Double Difference), Instrumental variable (IV)
Macro	Adoption	Systematic review, Simulation	Systematic review
	Impact	Systematic review, Economic surplus using model using DREAM model	Systematic review

Note The list provided is limited there are several other methods. Other approaches and methods are also listed and discussed in the Approaches, methods and techniques section
Source Authors creation based on review

Broadly we could classify the socio-economic assessment into ex ante and ex-post assessment. Ex ante assessment deals with socio-economic assessment done before introduction of technology while ex-post is done after introduction of technology. The assessment could be further classified as micro and macro studies. Micro studies are done at farm level and macro studies are ate region or country level.

Adoption studies

Assessment on adoption and diffusion of any technology is done to understand its scope and potential end users. About eight literatures were reviewed to understand the assessment methodology used in the study (Table 9.2). As there were few studies on adoption of GM crops in India few studies form other countries were reviewed for methodologies. Ex ante adoption studies were done at both micro and macro for crops, which are not currently cultivated. Ex-post adoption studies are done at micro level and macro level for the crops, which are already in cultivation. The details of different methodologies are given in table. For ex ante micro studies farm level data could be collected using random sampling at sub-regional level or multi-stage sampling and run binary regression models (logit/probit). In such cases farmers who had expressed interest in taking up the technology is considered as adopters (potential adopters) (see Kolady and Lesser 2006). For ex-post adoption assessment other than binary regression models we can employ tobit, heckman selection model or double hurdle model (see Mal et al. 2012). In such analysis both adoption and extent of adoption is also considered. Both ex ante and ex-post adoption at macro level could be done using systematic review and simulations (Graham and Barfoot 2005; Shelton et al. 2002). These methodologies are well suited in Indian context and there are growing number of studies carried out using these methodologies in India. In our case as GM brinjal and GM maize is yet to be introduced we had carried out ex ante adoption study with our data using a probit model.

Impact

Impact studies are done to understand the socio-economic and ecological implication of adoption of any technology (LMO crops in our case). A brief review of both ex ante and ex-post impact studies in India is shown in Table 9.3. Different methodologies are employed by researchers suiting the objective context and technology. For mirco-level ex ante studies simulations are ex ante economic surplus methods are commonly used (see Krishna and Matin 2007a, b), while for ex-post analysis Randomized Control Trail (RCT) (Fafchamps and Bart 2012), Propensity Score Matching (PSM) (Shiferaw et al. 2014), Double Difference (DD) (Quisumbing and Lauren 2010) and Instrumental Variable (IV) (Abadie 2003; Sadanandan 2014) are the most suitable methodologies. Problem with selectivity which arise because of OLS estimation could be solved using RCT, in which researcher could randomly assign farmers as users and non-users the challenges in implementing it, PSM also follows a similar approach but we need to oversample the non-adopters to get better match. IV approach; variable which is correlated with dependent variable put uncorrelated with other independent variables (read Khandker et al. 2010). The challenge in this method is getting good IV. Panel data gives a lot of flexibility in using approaches like DD, IV and fixed effect or random effect panel data models.

Table 9.2 Review on Adoption studies carried out in LMO

	Level		Author	Year	Journal	Crop	Region	Method	Sampling framework	Sample	Analytical tools	Data
1	Micro and Macro	Ex-Post	Wang et al.	2015	AgBioForum	Cotton	Cotton production zones		Na	na	FGD[a]	Panel
2	Micro and Macro		Lalitha and Viswanathan	2015	AgBioForum	Cotton	Gujarat	Dealers		82		
3	Micro	Ex-ante	Kolady and Lesser	2006	AgBioForum	Egg plant (brinjal)	Maharashtra	Farm level	Random at sub-regional level	290	Bivariate probit model	Cross-sectional
4	Micro	Ex-post	Kiresur and Manjunath	2011	Agricultural Economics Review	Cotton	Karnataka	Farm level	Multi-Stage sampling	60	Logit	
5	Micro	Ex-post	Mal et al.	2012	AgBioForum	Cotton	Haryana & Punjab	Farm level	Radom sampling	200	Double hurdle	Cross-sectional
6	Macro	Ex-ante	Smyth et al.	2013	Plant Biotechnol-ogy Journal	Banana		Macro data	Na			
7	Macro	Ex-post	Scandizzo and Sara	2010	AgBioForum	GM crops	13 States	Macro data: State level	Na	117	OLS[b]	Panel
8	Macro	Ex-post	Kumar and Swamy	2014	Current Biotica	Cotton	India	Review	Na	na		

Note [a]FGD—Focus Group Discussion, [b]OLS—Ordinary Least Square

Table 9.3 Review of impact studies in India on LMO

	Level		Author	Year	Journal	Crop	Region	Method	Sampling framework	Sample	Analytical tools	Data
1	Micro	Ex-ante	Krishna and Matin	2007b	AAEA, WAEA & CAES joint annual meeting	Egg plant(brinjal)	Andhra Pradesh, Karnataka, Karnataka, West Bengal	Farm level	Purposive and expert assessment	360	Simulation; economic surplus	Cross-sectional
2	Micro	Ex-post	Bennett et al.	2004	AgBioForum	Cotton	Maharashtra	Farm plot	Random sampling at three sub-regions	9000	Kruskal-wallis nonparamet-ric test	Panel
3	Micro	Ex-post	Pemsl et al.	2004	Crop protection	Cotton	Karnataka	farm level	na	100	Simulation; monte carlo	Cross-sectional
4	Micro	Ex-post	Crost et al.	2007	Journal of Agricultural Economics		Maharashtra	farm level	Random sampling at two sub-regions	718 plots 338 farmers	Fixed effects model	Panel
5	Micro	Ex-post	Subramanian and Qaim	2010	Journal of Development Studies	Cotton	Maharashtra	Households	Village census	305	Simulation; Social Accounting matrix	Cross-sectional
6	Micro	Ex-post	Kouser and Matin	2011	Ecological Economics	Cotton	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	Farm level	Multistage random sampling	198	Poisson panel regression	Panel
7	Micro	Ex-post	Kathage and Matin	2012	PNAS	Cotton	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	Farm level	Multistage random sampling	533	Fixed effects model and Random effect model	Panel

(continued)

Table 9.3 (continued)

	Level		Author	Year	Journal	Crop	Region	Method	Sampling framework	Sample	Analytical tools	Data
8	Micro	Ex-post	Krishna and Matin	2012	Agricultural Systems	Cotton	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	Farm level	Multistage random sampling	341 (base)	Fixed effect and random effects	Panel
9	Macro	Ex-ante	Shelton et al.	2002	Annual review of Entomology	Cotton, Corn, Potatoes	Global	Meta data	Purposive review	Na	Na	Na
10	Macro	Ex-post	Graham and Barfoot	2005	AgBioForum	Soyabean, maize, cotton, canola, other GM crops	US, Argentina, Brazil, Paraguay, Canada, South Africa, China, India, Australia, Mexico, Philippines, Romania, Uruguay, Spain, Other EU, Columbia, Bolivia, Myanmar, Pakistan, Burkina Faso, Honduras	Meta data	Purposive	Na	Tabular	Na
11	Macro	Ex-post	Marvier et al.	2007	Science	Cotton and Maize		Meta data	Systematic review	42		Na

(continued)

Table 9.3 (continued)

	Level		Author	Year	Journal	Crop	Region	Method	Sampling framework	Sample	Analytical tools	Data
12	Macro	Ex-post	Finger et al.	2011	Sustainability	Maize, Cotton	India, China, Australia, USA, South Africa, Spain, Germany, Argentina	Meta data	Systematic review	721	Linear regression model	Panel
13	Macro	Ex-post	Qaim and Shahzad	2013	PlosOne	Cotton	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu		Radom sampling	1431	Radom effect model	Panel
14	Macro	Ex-post	Klumper and Qaim	2014	PlosOne	All GM crops	Global	Meta Data	Systematic review	147	Na	Na
15	Macro	Ex-post	Brookes and Barfoot	2005		Soyabean, maize, cotton, canola, other GM crops	US, Argentina, Brazil, Paraguay, Canada, South Africa, China, India, Australia, Mexico, Philippines, Romania, Uruguay, Spain, Other EU, Columbia, Bolivia, Myanmar, Pakistan, Bukina Faso, Hnduras	Meta data	Purposive	18	Na	Na

(continued)

Table 9.3 (continued)

	Level		Author	Year	Journal	Crop	Region	Method	Sampling framework	Sample	Analytical tools	Data
16	Macro	Ex-post	Srivastava and Deepthi	2016	Current Science	Cotton	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Gujarat, Madhya Pradesh, Punjab, Haryana, Rajasthan	Macro data	Purposive: Maize growing states	162	Panel yield model	Panel
17	Macro	Ex-post	Pray et al.	2011		Cotton		Meta data		Na	Na	Panel

For macro level systematic reviews or economic surplus model using DREAM model (Wood et al. 1995) could be used. Various studies ex ante studies had been carried out using this model (Lusty and Smale 2002; Macharia et al. 2012a, b) The issues would be the availability of data for such assessment. For any impact assessment large sample size and preferably panel data helps in robust econometric analysis.

9.2.2 Perception Studies

Perception studies are generally undertaken to understand what people think about the technology. This studies are with lot of subjectivity, nevertheless if well design it could give us a good indicator about the acceptance of technology. For LMO this would be important aspect. Various studies used this approach for assessment of LMOs (see Carpenter 2010; Lucht 2015).

9.2.3 Prioritizing Methods

Before carrying out any socio-economic study a good understanding regarding the scope, objective and limitations are to be considered. A proposed order in which the socio-economic study to be done for any new LMO is given below.

1. Ex ante macro level assessment of impact: Social, environmental, economic, health and cultural impact. This would give us insights into whether the technology is required, its benefits and trade-offs.
2. Ex ante macro-level study on adoption. Who are the adopters and whether they are willing to adopt.
3. A perception study to understand how different stakeholders perceive the technology.
4. Ex ante micro-level study on impact and adoption of LMO.
5. While introducing the technology RCT could be done.
6. Ex-post micro-level impact assessment using PSM (cross-sectional data), DD & IV, panel data regressions (Panel data).
7. Macro level impact studies using DREAM or systematic reviews.

9.2.4 Socio-Economic (SE) Assessment of Maize and Brinjal

A study was carried out assess Maize and Brinjal (one trait each for which LMOs are available) and find the perception of the farmer.

9.3 Methodology

Study area
The study was conducted in the district of Nalagonda in Telangana where both the crops viz. Maize and Brinjal are grown. The area under food and other crops in Nalagonda is about 6.83 lakhs hectare. 42.36% of this area is irrigated. Main crops of Nalagonda are rice, pulses, cotton. However, Maize cultivation in the district is picking up. Brinjal is one of the important vegetable crops in Nalagonda. There are two KVKs in Nalagonda. Kampasagar is the KVK governed by PJTSAU, Hyderabad.

9.3.1 Sampling and Data Collection

The multistage sampling procedure was followed in the study. In the first stage we have selected district based on the prominence of Maize and Brinjal so that we can get sufficient number of respondents. In second stage, again the Mandal (Block) was selected based on the prominence of both the crop. To get maximum farmers, the advice of KVK Kampasagar was sought. Simple random sampling technique was used for selection of farmers at the last stage. Field investigators were hired and data were initially collected in Nalagonda District. The schedules were translated in Telugu for the better understanding by the investigators and their ease in asking the questions to the farmers. These investigators were trained for a day. A total of 250 farmers (125 each for brinjal and maize) were surveyed for the study.

9.3.2 Analytical Model

Simple frequency table and averages were estimated for the population. Tabular format was used for inferences of the preliminary result. Further as discussed in the section (Data and Methods) we had used probit to understand the ex ante adoption of LMO crops by farmers. This approach is used to understand the characteristics associated with adoption of LMOs. The empirical form of probit model is given as Eqs. 9.1 and 9.2.

$$Y = X^{'}\beta + \varepsilon \tag{9.1}$$

where $\varepsilon \sim$ N(0, 1). Then Y can be viewed as an indicator for whether this latent variable is positive, i.e.,

$$\begin{aligned} Y = 1 \quad & if\, Y > 0, \\ 0 \quad & otherwise \end{aligned} \tag{9.2}$$

And $X^{'}$ are individual, household, farm and trait specific characteristics.

9.4 Results and Discussion

The survey results were analysed and presented below for two clusters of villages in Nalagonda District. Villages in brinjal clusters (referred as Brinjal in table) are those where farmers grow substantial brinjal for income purpose. Similarly, Maize represent cluster of villages where maize is important crop.

9.4.1 General Information About Farmer, Household and Farm

Table 9.4 provides summary of the characteristics of the surveyed farmers (respondents). The average age of farmers growing brinjal and maize was 41.1 and 42 respectively. About 38.4% of brinjal farmers were illiterate while only 20% of maize farmers were illiterate. On an average the literacy rate of maize farmers were higher compared to the brinjal farmers. Most of the farmers 98.4% (brinjal) and 99.2% (maize) were dependent on agriculture or agriculture-related activities as their primary source of income.

Summary of household characteristics are given in Table 9.5. The average household size of brinjal farm household was 4.5 while it was 3.9 in case of maize farm household. The household level illiteracy was higher in case of maize farm households (13.6%) compared to brinjal farm households (8.0%). About 91.2% of brinjal farm households and 98.4% of maize farm households are nuclear family.

Table 9.4 General information about farmers in selected clusters

Particulars	Percent	
	Brinjal	Maize
Age (average)	41.1	42.2
Education level of farmer		
Illiterate	38.4	20.0
Primary education	24.8	42.4
Middle school education	11.2	3.2
Secondary education	19.2	21.6
Vocational training/education	2.4	4.8
Graduation and above	4.0	8.0
Primary source of income		
Agriculture-related activities	98.4	99.2
Other businesses	1.6	0.8
Service (private)	0	0
Service (govt.)	0	0

Source Data collected from surveys

Table 9.5 General information about farm households in selected clusters

Particulars	Percent	
	Brinjal	Maize
Household size (average)	4.5	3.9
Highest level of education		
Illiterate	8.0	13.6
Primary education	20.0	33.6
Middle school education	16.8	3.2
Secondary education	16.8	24.0
Vocational training/education	16.0	4.8
Graduation and above	22.4	20.8
Family Type		
Nuclear	91.2	98.4
Joint	8.8	1.6
Primary source of income		
Agriculture-related activities	99.2	100
Other businesses	0.8	0
Service (private)	0	0
Service (govt.)	0	0

Source Data collected from surveys

Agriculture-related activities are the primary source of income for most of the brinjal (99.2%) and maize (100%) farm households.

9.4.2 Farm Characteristics

Table 9.6 shows the characteristics of brinjal and maize farm. Majority of brinjal farmers were marginal land holders (47.5%) while maize farmers were small (36.8%) and semi-medium (32.0%) land holders. Red soil is the predominant soil type of both the brinjal and maize farms. Most of the farmers; 96.0% (brinjal) and 96.8% (maize) owns the land. About 68.2% of brinjal and 73.7% of maize farm lands are irrigated.

9.4.3 Cropping System in Selected Clusters

Information regarding cultivation of crops by farmers is shown in Table 9.7. Most of the farmers stated that they follow the recommended practices. The average total land holding of brinjal farmers is 1.75 ha and maize farmer is 1.71 ha. Brinjal is on an average of 15% (0.24 ha) of their total land holding and maize is cultivated on 60%

Table 9.6 Farm related characteristics if brinjal and maize farmer in selected clusters

Particulars	Percent	
	Brinjal	Maize
Landholding		
Marginal (below 1 ha)	47.5	27.2
Small (1–2 ha)	22.1	36.8
Semi-medium (2–4 ha)	21.3	32.0
Medium (4–10 ha)	6.6	4.0
Large (more than 10 ha)	2.5	0.0
Soil type		
Black	1.6	4.8
Red	96.0	87.2
Both (red and black)	1.6	1.6
Other	0.8	6.4
Nature of land holding		
Leased-in	8.0	2.4
Leased-out	4.8	1.6
Owned	96.0	96.8
Irrigation		
Irrigated land share	68.2	73.7

Source Data collected from surveys

Table 9.7 Cropping details of farmers in selected clusters

Particulars	Brinjal		Maize	
	2013–14	2014–15	2013–14	2014–15
Recommended practices (% Farmer)	100.00	100.00	96.00	97.60
Average total land holding (ha)	1.75	1.75	1.71	1.71
Average area under crop cultivation (Ha)	0.24	0.23	0.98	1.03
Average price (Rs/Q)	1088.76	1094.17	1021.54	1029.5
Average productivity/yield (Q/Ha)	449.5	375.4	45.5	33.26

Source Data collected from surveys

of their total area. The average price of brinjal was Rs. 1,088.76 in 2013–14 and Rs. 1094.17 in 2014–15. The average price of maize was Rs. 1021.54 in 2013–14 and Rs. 1029.5 in 2014–15. Thought drought had reduced the production in both the crops there were no significant improvement in prices. The average productivity reported by farmers were around 551 Q/ha in 2013–14 and was 517 Q/ha in 2014–15. The average productivity of maize was 45.5 Q/ha in 2013–14 and 33.26 Q/ha in 2014–15.

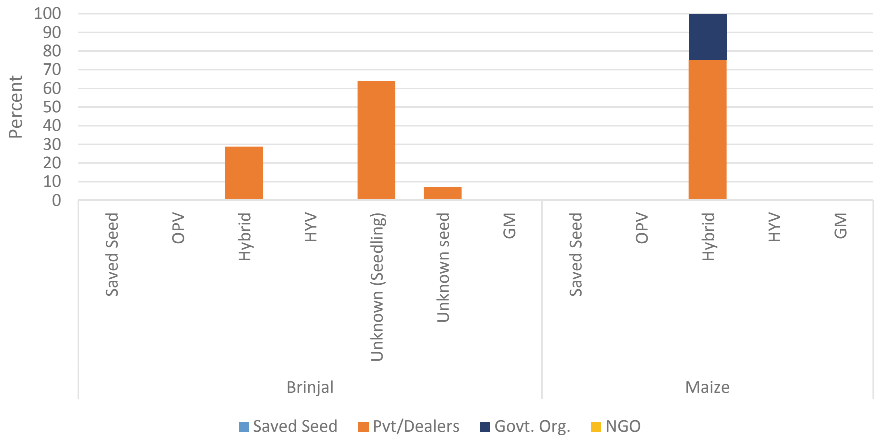

Fig. 9.1 Source of seed preferred by farmers. *Source* Data collected from surveys

9.4.4 Major Crops

Paddy is the crop all farmers grow in their field with varying percentage of area under it. This crop is grown in all three seasons, i.e. Kharif, Rabi and Summer. However the majority of area sown is in Kharif season. This was followed by pulses, oilseeds and maize. In vegetables major crops are Chillies, Brinjal and lady's finger. These crops are for supply of vegetables to Hyderabad and Vijayawada.

9.4.5 Source of Seed

The source wise share of seeds is shown in Fig. 9.1. In brinjal farmers buy hybrids (28.8%), seedlings (64.0%) and also unknown seeds (7.2%). They all buy the seeds/seedlings from private dealers. The hybrid brinjal seeds cost on an average of Rs. 200 per 100 g, seedlings cost roughly Rs. 130 for 100 seedlings. The farmers buying unknown seeds are paying higher price (Rs. 275/100 g). In maize farmers grow mainly hybrids and 75% of them get seeds from private dealers and 25% of them get seeds from government sources. For maize the average seeds cost per kg is around Rs. 150.

9.4.6 Factor Influencing Selection of Seed Source

The farmers were asked to list the major factors which they consider while choosing the source of seed. In case of brinjal good quality of seed (43.20%) followed by trust

Table 9.8 Factors influencing selection of seed sources among farmers

Reason	Percent	
	Brinjal	Maize
Good price	10.40	57.60
Good quality	43.20	40.80
Closeness to home	22.40	0.00
Trust on seed source	24.00	1.60

Source Data collected from surveys

on source (24.00%), closeness to home (22.40%) were the major factors. Closeness to home became a factors here because many of they buy seedlings instead of seed in case of brinjal. In case of maize price of seed (57.60%) followed by quality of seed (40.80%). In case of both brinjal and maize quality of seed is a major issue most of them reported that they are receiving spurious seeds (Table 9.8).

9.4.7 Pesticides and Herbicides

Among the reported pesticides (Table 9.9), about 27 pesticides could be identified and 18 pesticides could not be identified. The major pesticide used by the farmers against pests in rice and other vegetables including brinjal was found to be corazen. Caldon was used in Brinjal against shoot and fruit borer, Jassid, Whitefly, major pests of Brinjal. However, many farmers use these pesticides on the recommendation of retailer.

Carbofuran is one of the most toxic carbamate insecticides but reported to be used maximum in the maize cluster (Table 9.10). It is used to control insects in a wide variety of field crops mostly rice and maize. Again farmers have reported to using these pesticides based on the recommendation of the retailers rather than any

Table 9.9 Pesticides used by brinjal cluster farmers in Nalgonda district

Pesticides	Percentage	Frequency
Corazen	40.0	50
Messile	9.6	12
Caldon	6.4	8
Carbaryl	5.6	7
Copperoxychloride	4.8	6
Fipronil	4.8	6
Monocrotophos	4.8	6

Source Data collected from surveys
Note Multiple response. > 40% of farmers were also using pesticides which could not be identified by name
Source Survey data, 2016

Table 9.10 Pesticides used by maize cluster farmers in Nalgonda district

Pesticide	Percentage	Frequency
Carbofuran 3g	59.2	74
Coragen	6.4	8
Phorate	4.0	5
Carbofuran 10g	3.2	4
Carbofuran 4g	2.4	3
Dithane M-45	2.4	3
Fipronil 4G	1.6	2
Carbofuran	1.6	2
Emamectin Benzoate	1.6	2
Gullikalu 10g	1.6	2
Fipronil 4G	0.8	1

Note Multiple response. Seven pesticides couldn't be identified
Source Data collected from surveys

agri-professional. Besides some of the fungicides like Dithane M-45 and Fipronil were also reported to be used in this area.

Farmers in brinjal cluster do not use any herbicides for weed control. In maize Atrazine (85.6%) and Paraquat (52.8%) are commonly used.

9.4.8 Volume of Pesticide

Both brinjal and maize farmers reported that they use less than or recommended volumes of insecticides and herbicides (Table 9.11). Brinjal farmers reported that about 60.8% of then use less than recommended dose and 39.2% of them use recommended

Table 9.11 Volume of pesticides applied by farmers

	Percent	
	Brinjal	Maize
Use insecticide		
More than recommended	0.0	0.0
Less than recommended	60.8	59.2
Recommended volume	39.2	40.8
Herbicide		
More than recommended	0.0	0.0
Less than recommended	68.0	57.6
Recommended volume	32.0	42.4

Source Data collected from surveys

volume of herbicide. Maize farmers reported that about 59.2% of them use less than and 40.8% follow recommended volume of pesticide. The same pattern was observed in case of herbicides where brinjal farmers stated that 68.0% of them following less than recommended dose and 32.0% of them followed recommended dose. Among maize farmers 57.6% of them used herbicides at rates less than recommended 42.4% of them used recommended volume.

9.4.9 Yield of Crop Under Various Scenarios

Farmers were asked to report production of crops under six scenarios based on their experience. The scenarios were lowest yield with absence of problem, highest yield with absence of problem, lowest yield with presence of problem, highest yield with presence of problem, lowest yield with presence of problem and remedial measure, highest yield with presence of problem and remedial measure. The results are depicted using box plots for brinjal (Fig. 9.2) and maize (Fig. 9.3). The yield are given in quintals per hectare. Due to small area under brinjal cultivation farmers had overstated yield and higher variability was also observed. Overall no significant improvement in yield was observed even after undertaking remedial measures.

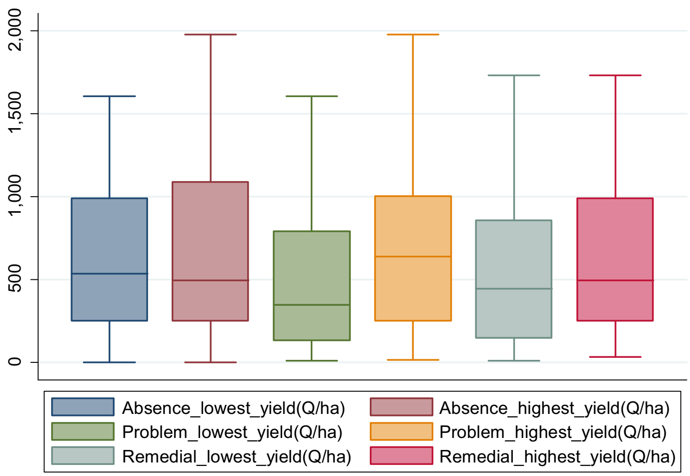

Fig. 9.2 Production scenarios of brinjal under different scenario in Nalgonda district. *Source* Data collected from surveys

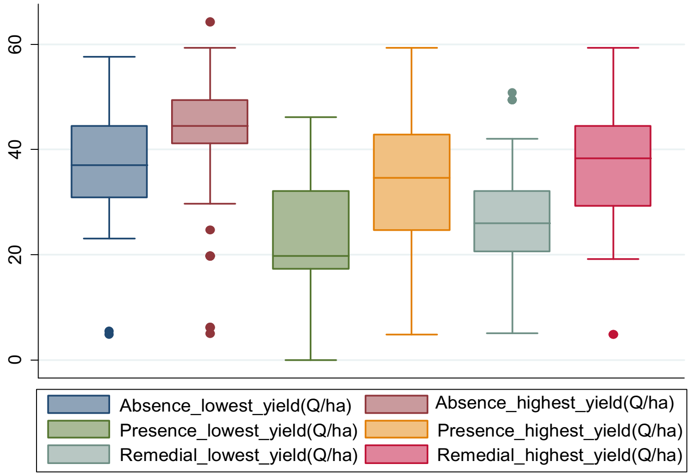

Fig. 9.3 Production scenarios of maize under different scenario in Nalgonda district. *Source Data collected from surveys*

9.4.10 *Major Constraints in Production*

The major constraints in production of crop were elicited in the survey (Table 9.12). Insect attack (22.4%) was recorded as major constraint in case of brinjal followed by drought. In case of maize insect and weeds were the major constraints in 2013–14 and in 2014–15 it was drought (73.6%).

Table 9.12 Major constraints in production reported by farmer

Particulars	Percent			
	Brinjal		Maize	
	2013–14	2014–15	2013–14	2014–15
Drought	4.8	19.2	0	73.6
Diseases	1.6	0.8	0	0
Insect	32.0	22.4	15.2	4.8
Weed	3.2	3.2	11.2	6.4
No Response	54.4	53.6	72	15.2
rain	4	0.8	1.6	0

Source Data collected from surveys

9.4.11 Cost–Benefit Analysis

The cost of cultivation (total variable cost) and benefits were calculated and depicted in Table 9.13. Returns to fixed cost was and benefits with preferred trait under different scenario of increase in seed cost (10, 25, 50%) and yield increase (5, 10%).

Cost of cultivation of Brinjal and Maize is presented in Table 9.13. Total variable cost of Brinjal is about Rs. 91,188/-. The major portion of this is expended in Insecticides (about 16.94%), followed by seedling (direct purchase of seedlings/raising seedlings) and manual weeding (14.29%). This is important indication for intervention in insect resistant varieties. There are many Bt brinjal varieties, which will reduce the cost of insecticide. A sensitivity analysis was also carried out in the crop. It is assumed that cost GM seeds of brinjal will increase at the rate of 10, 25 and 50% and the yield level may remain same, increase by 5 and 10%. It can be easily inferred that except when seed cost increased by 50% and yield remain same then benefit to cost ratio is less than one and no one want to take the seed. Otherwise benefit to cost ratios were fairly good enough to adopt the GMOs s.t. other costs remain same.

Referring to cost of maize from the table, it is clear that maize farmers spend about Rs. 28,966/- per hectare out of which the share of weeding from different methods is about 14.24% which include cost of herbicide, its application and manual weeding. Other important operations are cost of seed, cost of fertilizer, land preparation. To reduce the cost of weeding through different method maize hybrids can be modified through genetic engineering. These GMOs in maize would increase the profitability. Again sensitivity analysis show, that in maize, adoption of GMOs without the yield increase, will be profitable at 10% of increase in cost of seed. However the if there is increase in yield even by 5% and cost of seed by 50%, the crop is marginally beneficial over existing profitability. From farmer's point of view 10% increase in yield and seed cost would be most beneficial.

9.4.12 Willingness to Pay for Preferred Trait More Than Present Value

Farmers were explained about the desired LMO (pest and weed tolerant trait for brinjal and maize respectively) and asked about their willingness to pay for the seed (Table 9.14). About 63.2% of farmers were willing to pay more than 50 and 28% of them were ready to pay more than 10% (<25%). In case of maize, farmer 46.4% of them were willing to more than 10% (<25%) and 41.6% of them were willing to pay more than 50%. Willingness to pay is higher in case of brinjal farmer's as they anticipates improvement in yield (more number of non-infested fruits due to less fruit borer infestation) as well as reduction in cost (reduced insecticide) application. While in case of maize farmers they anticipate only reduction in cost of herbicide application.

Table 9.13 Cost and benefit analysis of brinjal and maize in selected clusters

Particular	Brinjal		Maize	
	Rs/Ha	Share (%)	Rs/Ha	Share (%)
Seed/Seedling	16437	15.81	3536	12.21
Fertilizer	6436	6.19	4984	17.21
Insecticide	17612	16.94	1402	4.84
Herbicide	0	0.00	1070	3.69
land preparation	11656	11.21	4494	15.51
Planting	9108	8.76	3696	12.76
Irrigation	3669	3.53	453	1.56
Labour for fertilizer application	6071	5.84	1862	6.43
Labour for insecticide application	5704	5.49	817	2.82
Labour for herbicide application	0	0.00	705	2.43
Weeding	2070	14.29	2353	8.12
Harvesting	7707	7.41	2167	7.48
Post harvesting and transportation	4718	4.54	1427	4.93
Total variable cost	91188		28966	
Total value[a]	408750		40800	
Return to fixed farm resources[b]	317562		11834	
Cost saved[c]	23316		4128	
Total Variable cost with preferred trait[d]	67872		24838	
Benefit with preferred trait LMO[e]	340878	*1.073*	15962	*1.350*
With 10% increased seed cost	322797	*1.016*	12072	*1.020*
With 25% increased seed cost	320332	*1.009*	11542	*0.975*
With 50% increased seed cost	316223	*0.996*	10658	*0.901*
With 5% increase in yield with 10% increase seed cost	322047	*1.014*	14112	*1.193*
With 10% increase in yield with 10% increase seed cost	347547	*1.094*	16152	*1.365*
With 5% increase in yield with 25% increase seed cost	319582	*1.006*	13582	*1.148*
With 10% increase in yield with 25% increase seed cost	345082	*1.087*	15622	*1.320*
With 5% increase in yield with 50% increase seed cost	319582	*1.006*	12698	*1.073*
With 10% increase in yield with 50% increase seed cost	345082	*1.087*	14738	*1.245*

Note [a]Average yield multiplied by average price, [b]Total value—total variable cost, [c]Summation of cost saved by the preferred trait, [d]Total variable cost—cost saved, [e]Total value—total variable cost with preferred trait. The number italicized inside the table are ratios to respective benefits to the return to fixed farm resources

Source Data collected from surveys

Table 9.14 Farmers willingness to pay for desired trait

Price	Percent	
	Brinjal	Maize
More than 50%	63.2	41.6
More than 25%	6.4	11.2
More than 10%	28.0	46.4
Less than 10%	2.4	0.8

Source Data collected from surveys

Table 9.15 Awareness about GM crops among farmers

Particulars	Percent	
	Brinjal	Maize
Aware	4.0	3.2
Not aware	96.0	96.8
GM crop known	Cotton	Cotton
GM crop grown	4.0	0.0

Source Data collected from surveys

9.4.13 Awareness About GM Crop

Farmers were asked about their prior awareness and experience with GM crop (Table 9.15). Most of them were not aware of GM crop; brinjal farmers (96.0%) and maize farmers (96.8%). The few who are aware about GM crops had cultivated cotton.

9.4.14 Opinion About GM Crop

Farmers were asked about their opinion and their willingness to adopt such variety. We should be caution in drawing inference form the table as their knowledge about GM crop is limited and the present context is drawn based on the explanation given by the enumerators. However, with this limited information given to them, majority of the brinjal and maize farmers had expressed their opinion that GM crops are not harmful for human and livestock. About 58.4% of brinjal farmers and about 76.0% of maize farmers expressed their interest to adopt GM crop with the desired trait (Table 9.16).

Table 9.16 Opinion about GM pinion about GM crops among farmers

Opinions	Percent					
	Brinjal			Maize		
	Yes	No	No response	Yes	No	No response
GM harmful to human	6.4	92.8	0.8	3.2	93.6	3.2
GM harmful to livestock	5.6	93.6	0.8	1.6	95.2	3.2
Adopt GM crop	58.4	40.0	1.6	76.0	22.4	1.6

Source Data collected from surveys

9.4.15 Adoption of LMO Crop: An Ex ante Analysis

As both brinjal and maize LMO (GM) crop technology is not available we asked about their willingness to adopt the technology. From Table 9.17, we could see that 58.4%

Table 9.17 Factors influencing adoption: empirical evidences through probit analysis

	Brinjal			Maize		
	Coef.	Std. Err.	P > z	Coef.	Std. Err.	P > z
Age	0.413	0.158	0.009	0.217	0.119	0.068
Age square	−0.004	0.002	0.011	−0.002	0.001	0.078
Household size	0.941	0.524	0.073	−0.006	0.118	0.957
Farmers education	−0.016	0.339	0.964	−0.899	0.369	0.015
Household education	−0.265	0.404	0.511	−0.105	0.421	0.803
Seed	−0.400	0.326	0.220			
Pesticide cost	0.000	0.000	0.187	0.000	0.000	0.084
Herbicide cost				0.000	0.000	0.426
Total land holding				−3.011	1.512	0.046
Area under crop				1.439	1.171	0.219
Share of cultivated crop	−0.006	0.007	0.354			
Irrigated area (%)	0.010	0.005	0.051	−0.003	0.005	0.609
Irrigation source	0.536	0.309	0.084	0.114	0.295	0.700
Extension contact	0.163	0.393	0.678			
Number of obs	101			124		
LR chi2 (11)	21.57			23.160		
Prob > chi^2	0.0279			0.017		
Pseudo R^2	0.1601			0.169		
Log likelihood	−56.58			−57.031		

Source Data collected from surveys

and 76.0% of farmers are ready to accept the GM crop of particular trait in brinjal and maize respectively. To understand the factors determining their willingness to adopt, an ex ante adoption study was one using probit model. The results from the model are shown in table. In case of brinjal factors such as age, household size, and percentage of irrigated area and presence of tube are positively influencing adoption of GM brinjal and farmers with this characteristic are more likely to adopt GM crops. But farmers with higher age are less likely to adopt. These findings are on par with findings from various studies and they are mostly the early adopters. Other trait specific characteristics (pesticide cost) was not influencing adoption of GM crop. In case of maize similar variables were find to be influencing adoption. In addition, total land area had shown negative relationship with adoption of GM crops. Smaller and marginal farmers are more likely to adopt GM crops. Trait specific variable (herbicide cost) was found to insignificant while pesticide cost was found to significant factors (at 10% significance level). The results are preliminary and more detailed analysis including other variable are to be undertaken.

9.5 Summary and Conclusion

There are different methods of analysis used to study adoption and impact of Genetically Modified Organisms. For socio-economic study on brinjal and maize LMO, an ex ante approach was used to study adoption. The results from cost–benefit ratio shows that at present level, assuming that the cost of seeds of GM crop will be more as compared to conventional crops, there should also be yield advantage in both brinjal and maize to gain net profits. Several factors such as age, cost of pesticide and insecticides, irrigation area would influence the adoption of brinjal and maize LMOs. Farmers were found to be willing to pay more for alternative crop varieties (HYV, Hybrid, GM, etc.) in different crops, provided that variety would increase their profitability. It was also found that the farmers should be made aware properly before introduction, so that they can take all precautions that are needed to raise a genetically modified crop. Farmers were also of the opinion that there should be proper regulatory mechanism in place for environmental safety for new varieties (GMOs, LMOs).

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Chapter 10
Socio-economic Assessment of Aerobic Rice and Bt Cotton in Karnataka

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Abstract Farm household data was collected from 50 aerobic rice and 100 Bt cotton farmers in Karnataka for socio-economic assessment with special focus on drought tolerance trait of aerobic rice and insect resistance trait of Bt Cotton. Results indicated that age and education are not a limiting factor for cultivation of aerobic rice and Bt cotton, whereas size of the operational holding had an influence on its cultivation. The drought tolerant trait was amply visible through significant amount of water saving in the case of aerobic rice and reduced use of insecticides with respect to Bt cotton. Dissemination of proper and authentic knowledge about GM crops through training and demonstration would go a long way in convincing farming community towards cultivation of GM crops. It is extremely essential that the GM crops in agriculture are offered to farmers as a package and concurrent assessment of this package is crucial for its sustainability.

Keywords Aerobic rice · Bt cotton · Cost–benefit analysis · GM crop · Karnataka

10.1 Introduction

Bt Cotton (GM crop) and Aerobic rice (Non-GM crop) has been considered for socio-economic assessment in this study. Brief background on the cultivation practices and experience of farmers on these two crops are presented below.

Aerobic Rice Cultivation of paddy is not only labour-intensive but also demands a large quantity of water and usually grown under submerged conditions. It is estimated that 5000 l of water is needed to produce one kilogram of rice. Given this essential resource requirement, the dwindling water resources reveal a grim situation for low land puddle rice cultivation. Rice cultivation is in crisis all over world and India is no exception to it, with its shrinking area under rice cultivation, fluctuating annual production levels, stagnant yields, water scarcity, and escalating input costs. The cost of cultivation of paddy has consistently been increasing, owing to escalating costs

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of labour and agrochemical inputs. On priority, several field experiments are being conducted for reducing water requirement of paddy cultivation.

Globally, there are two types of cultivation practices followed by farmers namely, Conventional and System of Rice Intensification (SRI) method. In conventional method, rice is grown on standing water flooded in the field. The SRI method involves cultivating rice with as much organic manure as possible, starting with young seedlings planted individually at wider spacing in a square pattern and with intermittent irrigation that keeps the soil moisture but not inundated, and frequent inter-cultivation with weeder that actively aerates the soil (Thiyagarajan and Gujja 2013). To keep up the rice production during irrigation water shortage, an alternate method of rice cultivation is vital. As such, International Rice Research Institute coined the term as 'aerobic rice' (Bouman et al. 2002). Aerobic rice is the cultivation of rice in non-submerged and un-puddled conditions in aerated soils. This method of cultivation involves direct seeding with surface irrigations when required and is characterized by aerated soil environment during the entire period of crop growth. Irrigation is given at an interval of 5 days up to 25 days, 5–7 days once up to 50 days and during grain filling stage irrigation is provided once in 5 days (Hittalmani 2007).

In 2007, the first drought tolerant aerobic rice variety MAS 946-1 was officially released in India. In the following year, MAS 26 variety was released for aerobic cultivation. Both these aerobic varieties were developed by University of Agricultural Sciences, Bangalore. Studies reported that aerobic rice can save about 50–60% of irrigation water. It is also reported that the amount of methane emitted under aerobic situation is very low and contributes to lowering of greenhouse gas emission (Hittalmani 2007).

In Karnataka, rice was cultivated in an area of 1.2 million hectares in 2012–13. Nearly 88% of this paddy cultivated area was concentrated in 14 districts and the other 12% in the remaining 16 districts of the state. Raichur district covers 11.86% of total area, followed by Shivamogga (9.64%) and Davanagere (9.14%) (DES 2013a, b). Area under rice cultivation had decreased from 1.54 million ha during 2010–11 to 1.28 million ha during 2012–13. Even production has decreased from 4.3 million tons to 3.36 million tons. However, the variation in productivity was minimal. Aerobic rice in particular, was mainly bred for South Eastern Dry Zone of Karnataka (Gandhi et al. 2012). At present aerobic rice cultivation is in the initial stage and it is being grown in patches of Mandya and Tumkur districts of Karnataka.

Bt Cotton Cotton is a major commercial crop of Karnataka grown in almost all agro-climatic zones of the state. All the four cultivated species of cotton are grown, while, *Gossypium hirsutum* comprises a major share of the cotton hybrids that are grown in the state. The type of cotton grown is mainly of medium staple and farmers normally rotate cotton with sorghum, maize, sugarcane and banana crops to avoid pest and diseases.

Bt Cotton was released in 2002 for commercial cultivation in India. The performance of two varieties of Bt Cotton were reported by the Department of Agriculture, Karnataka namely MECH Bt 162 and MECH Bt 184 that were cultivated on trial basis in 2002–03 in an area of 5379 and 22 acres, respectively in 8 districts of Karnataka. The report mentioned that there were wide variations from one district to another with respect to yield. For instance, the yield of Bt Cotton in Davanagere was 27.15 Qtls per ha, whereas it was only 7.50 Qtls per ha in Raichur. There was also the incidence of sucking pest in Bt Cotton fields in all trial districts. Such variations in yield as well as incidence of sucking pest were observed in traditional cotton fields in all the eight districts that were under trial. Although, Bt Cotton fetched lesser market price than traditional cotton, the trails were continued for two more years and later commercialised due to its advantages over conventional varieties.

Out of 30 districts in the state, cotton is cultivated in 23 districts. The area under cotton during 2012–13 was 4.97 lakh hectares which account for 5.72% of total gross cropped area of the state. Out of this, half of the cotton area was in four districts, namely Haveri, Bellary, Yadgir and Raichur. Another 10 districts accounted for 48.5% of the cotton cultivated area. Overall, cotton was grown mainly in 14 districts of the state. Yadgir (3.07 bales of 178 kg each) and Raichur (3.27 bales of 178 kg each) have indicated highest per hectare yield of cotton in Karnataka. The state has an area of 497,020 ha with a productivity of 2.19 bales of 178 kg each (DES 2013a, b).

Given this background, the specific objectives of the study are: (i) To estimate the cost of cultivation of aerobic versus conventional rice and Bt cotton, (ii) To analyse input management with special focus on trait related information (drought tolerant and insect resistance), and (iii) To study the perception about GM crops from farmers, scientists, input dealers and cotton traders.

This study is organised into five sections. Second section focuses on data, study area and the analytical approach. This section is followed by results and discussion, which is presented in three sub-sections namely; (i) socio-economics of sample households and cropping pattern, (ii) cost of cultivation of aerobic versus conventional rice, and Bt cotton, and (iii) trait related findings (drought tolerant and insect resistance). The final section presents the conclusions of assessment.

10.2 Methodology

Two crops and two traits were considered for the primary survey. Drought-tolerant trait in aerobic rice and insect resistance trait in Bt cotton. Primary data was collected in Mandya district of Karnataka in October 2015 for Aerobic rice. The underlying reasons for selection of Mandya are; the district had the highest area under aerobic paddy as per the records of University of Agricultural Sciences, Bengaluru and the district ranked first in terms of productivity of rice (3120 kg/ha). Primary data was collected from 50 aerobic rice farmers using purposive sampling in the only two taluks (Mandya and Maddur) where farmers cultivated aerobic rice in the district. Out of the 50 aerobic farmers, 32 farmers have also grown conventional rice. The questionnaire designed for the study covered socio-economic status, land holding, cropping pattern trait related information on seed, pest, disease and weed management and perception of farmers about GMOs.

With respect to Bt cotton, primary data was collected from Haveri district of Karnataka in December 2015 as the district ranked first in terms of area and production. Data was collected from 100 Bt Cotton cultivating farmers spread over all the 7 taluks of district using random sampling.

In order to fulfil the objectives, descriptive analysis was carried out to understand socio-economic characteristics of households. Performance of aerobic rice and conventional rice were examined with cost benefit analysis where social criteria were also considered. Gross margins have been computed by including irrigation cost (amortized cost technique at 3% real interest rate) for Bt cotton and irrigation charges per season for Aerobic rice, as it is grown under surface water. While computing the cost of production of crops, expenses on seeds, manure and chemical fertilizers, plant protection chemicals, bullock labour (both hired and owned), Machine power, human labour (both hired and family labour), marketing costs and irrigation cost were obtained. For computing the returns, the gross value of the output per farm from crop was calculated by multiplying production with the post-harvest price realised by the farmer. In addition, qualitative techniques were also used to understand the perceptions of these farmers.

10.3 Results and Discussion

10.3.1 Socio-economic Characteristics

Age, Gender family size, education status and experience in cultivation of conventional and aerobic rice/Bt cotton Age, Gender family size, education status and experience in cultivation of conventional and aerobic rice/Bt cotton have been presented in Table 10.1. All sample farmers were male and their average age was 44 years. Nearly 12% of them were senior citizens aged above 60 years and 70% were middle aged (35–59 years) and the others were below 35 years of age. The average family size of the farmers ranged from four to five members. Nearly 26% of total farmers were educated up to matriculation, 20% completed up to middle school and 24% were illiterates. Graduates were in the age group of 35–50 years.

With respect to Bt cotton farmers, 99% were male and their average age was 45 years. Around 9% of them were senior citizens and 2% were youngsters aged between 20 and 25 years. The average family size ranged between 5 and 6 members that comprised of two to three male members, one to two female members and one to two children. All illiterates were senior citizens and all graduates were in the age group of 28–38 years.

Most farmers have been farming on an average for approximately two decades. The aerobic farmers surveyed had an average cultivation experience of 18 years in conventional rice and lesser than 5 years in aerobic rice. While in the case of Bt cotton farmers, conventional cotton growing experience was 17 years and Bt cotton was 6–7 years.

Table 10.1 Age, gender, family size and education status

Particular	Units	Description	Aerobic rice	Bt cotton
Age	No. of farmers to total in %	Below 40 years	44.00	38
		Between 40 and 60 years	48.00	53
		Above 60 years	6.00	9
	No. of years	Average	44	45
Gender	No. of farmers to total in %	Male	100.00	99.00
		Female	0.00	1.00
Family size	Number per farm HH	Male	2.08	2.38
		Female	1.82	1.93
		Children	0.62	1.29
		Average	4.52	5.60
Education	No. of farmers to total in %	Illiterates	24.00	3.00
		Primary school	6.00	21.00
		Middle school	20.00	25.00
		High School	26.00	23.00
		Matriculates	14.00	19.00
		Graduates	10.00	7.00
	Number	Average	7.00	8.00

Source Data collected from surveys

Operational Land Holdings The average operational holding size of the aerobic farmers was 2.56 acres. This entire area was irrigated. Around 58% of area operated by farmers was red sandy soil, 30% was black soil and 12% was combination of red and black soil. Nearly 28% of sample farmers had tube well in addition to canal irrigation. While, the average operational holding size of the Bt cotton farmers was 8.82 acres. Out of this, 75% was rainfed and 25% was irrigated. Around 57% of the area operated by farmers was black soil, 25% was red soil and rest 18% was combination of black and red. Tube well was the only source of irrigation.

With respect to aerobic rice, nearly 66% of marginal and small farmers operated 87% of land and 4% of medium farmers operated 13% of land. Whereas in the case of Bt cotton, 30% of the marginal and small farmers operated 13% of land, 48% of medium farmers operated 42% of the land and 45% of large farmers operated 18% of land. The average operational land was 2.55 acres in the case of aerobic farmers, whereas it was 8.82 with respect to Bt cotton farmers.

Cropping Pattern The cropping pattern of aerobic rice farmers is presented in Table 10.2. The traditional crops of Mandya district are Paddy, Ragi, Maize and Jowar among cereals and the major pulses are cowpea, green gram, broad beans, red gram and tur. The important oilseed crops cultivated in the district are groundnut,

Table 10.2 Cropping pattern of aerobic rice farmers

Season	Crop	% of farmers	% area to season	Yield/acre
Kharif	Conventional rice	26	23.27	24.76
	Aerobic rice	74	62.68	21.39
	Ragi	22	13.06	15.14
	Tomato	2	0.64	31.11
	Lady's finger	2	0.35	60.00
	Kharif total	126	100.00 (41.67)[a]	21.55
Rabi	Conventional rice	58	70.73	19.46
	Aerobic rice	24	29.27	20.51
	Rabi total	82	100.00 (25.00)[a]	19.78
Summer	Ragi	14	70.00	19.26
	Sesamum	2	10.00	1.00
	Lady's finger	2	10.00	22.00
	Fodder	2	10.00	18.00
	Summer total	20	100.00 (4.64)[a]	16.95
Annual/Perennial	Sugarcane	74	100.00	374.15
	Annual/Perennial total	74	100.00 (28.69)[a]	374.15
	Grand total	302	100.00	122.07
	Total (acres)		169.90	

Source Data collected from surveys
Note Total may exceed sample size as sample farmers had cultivated more than one crop
[a]Figures in the parenthesis indicates per centage to the total gross cropped area

sesame and castor. Sugarcane is the important commercial crop and in recent years. Fruits and vegetables have also been given priority because of scarcity of water.

A majority of aerobic rice farmers also cultivated conventional rice. Ragi was the other important cereal crop cultivated by farmers. Tomato, Okra and Sesamum, were also grown. It is to note that most of the farmers have cultivated crops in Kharif and depending upon the water availability from canals, they have grown crops during Rabi and Summer. The Kharif accounted for 42% of the gross cropped area followed by Rabi (25%) and Summer (4%) and nearly 29% was sugarcane, an annual crop.

Aerobic rice was cultivated by three-fourth of the farmers in Kharif and only a quarter in Rabi. Nearly 34% of the area was under aerobic rice and 27% was under conventional rice. Thus, 61% of the gross cropped area was solely under rice crop. In Kharif, productivity of conventional rice was higher by 3.37 quintals per acre as compared to aerobic rice. Although aerobic rice had higher productivity than conventional rice in Rabi, the difference was only 1.05 quintals per acre.

Overall, Paddy and sugarcane are the major crops in the study region because of access to Cauvery canal water. Out of the GCA of 169.9 acres, 34% of the area is under aerobic paddy cultivation and 27% of area is under conventional paddy cultivation. Income from paddy cultivation alone contributed 50% followed by sugarcane, 36%.

Area, production and yield of aerobic rice for the past 3 years indicated that area under cultivation of aerobic rice is increasing over time, whereas the productivity levels have been declining due to excessive input use and decline in soil fertility levels.

Cropping pattern of Bt cotton farmers is presented in Table 10.3. Major crops grown by these farmers include paddy, maize, jowar and wheat among cereal crops; sunflower, groundnut and sesamum among oil seeds and cabbage, tomato, cauliflower and chilli among vegetables. All farmers have cultivated crops in Kharif, which covered 69% of the total gross cropped area. While crops cultivated during Rabi accounted for 28%, in summer the cultivation was to an extent of only 3%. Yield of Bt cotton was lower during 2014–15 as compared with yield that was obtained during the years 2012–13 and 2013–14 Kharif. In summary, cotton, maize, jowar and groundnut are the major crops grown by the Bt cotton farmers. Net income was found to be higher with cotton and vegetable cultivation.

Table 10.3 Cropping pattern of Bt cotton farmers

Season	Crop	% of HH	% area to season	Per acre in Qtls
Kharif	Paddy	2	0.47	28.75
	Maize	80	24.73	17.78
	Jowar	2	0.35	8.33
	Groundnut	13	8.56	7.29
	Sesamum	1	0.23	20.00
	Soybeans	2	0.26	5.58
	Tomato	2	0.32	10.37
	Brinjal	2	0.20	40.00
	Cabbage	26	5.43	228.43
	Chilli	24	4.68	17.56
	Cauliflower	2	0.35	90.00
	Bt cotton	100	54.36	8.75
	Flower	1	0.06	14.00
	Total	257	100.00 (69.04)[a]	–
Rabi	Paddy	2	1.15	12.50
	Maize	21	18.24	17.64
	Jowar	75	63.14	5.43
	Wheat	1	1.15	2.50
	Chick pea	1	1.15	3.75
	Sunflower	4	3.18	5.36
	Tomato	4	2.02	192.86

(continued)

Table 10.3 (continued)

Season	Crop	% of HH	% area to season	Per acre in Qtls
	Tomato (seed)	2	0.29	1.04
	Tomato (op)	4	2.31	1.07
	Brinjal (seed)	1	0.14	0.56
	Cabbage	7	3.18	57.27
	Chilli	1	1.59	7.27
	Cauliflower	1	0.58	110.00
	Ridge gourd	2	0.58	1.15
	Flower	2	1.30	66.67
	Total	128	100.00 (27.93)[a]	–
Summer	Maize	4	55.00	23.18
	Jowar	1	10.00	5.00
	Groundnut	1	10.00	3.50
	Tomato	2	25.00	42.00
	Total	8	100.00 (1.61)[a]	
Annual/Perennial	Fruits (mango)	1	16.67	32.40
	Sugarcane	2	33.33	420.00
	Coconut (nos.)	3	50.00	2029.41
	Total	6	100.00 (1.42)[a]	–
	Grand total	399	100.00	–
	Total (acres)	–	1240.20	–

Source Data collected from surveys
Note Total may exceed sample size as sample farmers had cultivated more than one crop
[a]Figures in the parenthesis indicates per centage to the total gross cropped area

10.3.2 Cost–Benefit Analysis

The cost benefit analysis in this study has not considered the fixed expenses like rental value of land, depreciation, interest on working and fixed capital and so on.

Costs and Returns of Aerobic and Conventional Rice Aerobic and conventional rice was cultivated in Kharif and Rabi. While, the sowing period of aerobic and conventional rice remains same, the duration of conventional rice is 10–12 days more than the aerobic rice. The surveyed revealed that conventional rice was cultivated by only 68% of the farmers due to scarcity of water (Table 10.4).

Table 10.5 is on per acre costs and returns of aerobic and conventional rice shows that the cost of cultivation of aerobic rice was higher by 12% in Kharif and 5% in Rabi as compared to conventional rice. Except hired labour, the other costs incurred during Kharif are relatively higher in aerobic rice. Whereas in Rabi, except machine labour and family labour, the other costs remain relatively higher in the case of aerobic rice.

Table 10.4 Sowing time and duration of aerobic and conventional rice

Season	Particulars	Aerobic rice	Conventional rice
Kharif	No. of HH cultivated (% to total)	74.00	22.00
	Sowing time	Last week of July to 2nd week of August	Last week of July to 2nd week of August
	Duration	130–135 days	135–145 days. At time the duration may exceed by a week or so
Rabi	No. of HH cultivated (% to total)	26.00	46.00
	Sowing period	Last week of October to 1st week of November	Last week of October to 1st week of November
	Duration	130–135 days	135–145 days. At time the duration may exceed by a week or so

Source Data collected from surveys

Irrigation costs are assumed at Rs. 200 per acre as per the prevailing canal water charges for both crops across seasons.

It is interesting to note that the number of irrigations required for conventional rice was almost double as that of aerobic rice in both reasons. If real costs were to be considered for water use then total cost of conventional rice becomes much higher than the aerobic rice.

Yield levels of aerobic rice were comparatively higher than the conventional rice in both reasons. However, this difference was found to be insignificant. Overall, the net income per acre of aerobic rice was higher by 6% in Kharif and 11.5% in Rabi as compared to conventional rice in the respective seasons.

Cost of Cultivation of Bt Cotton In Kharif, rainfed cotton was normally sown in June 2nd week to July 2nd week, whereas irrigated cotton was sown between May 2nd week to July 2nd week and the duration of the crop was around 6 months. Table 10.6 on per acre costs and returns of Bt cotton in Kharif indicates a net return of Rs. 16,809 with a total cost of Rs. 21,013 and a yield of 8.75 quintals. Out of the total cost, Labour cost was highest followed by fertilizer and tractor charges. The impact of Bt cotton is reflected in the reduction of plant chemical usage, which accounted for only 7% of the total cost.

10.3.3 Trait-Related Results

The drought tolerant trait for aerobic rice and insect resistance trait for Bt cotton has been examined in this study in addition to the information on seeds.

Table 10.5 Per acre costs and returns of aerobic and conventional rice

Particulars		Unit	Kharif				Rabi			
			Aerobic		Conventional		Aerobic		Conventional	
			Qty	Value	Qty	Value	Qty	Value	Qty	Value
Hired labour	M	Mandays	10.25	2397	10.60	2534	16.81	2959	8.24	2376
	F	Mandays	20.19	2658	20.60	2534	28.02	2589	14.04	2398
Family labour	M	Mandays	13.16	3073	12.49	2987	17.85	3141	12.14	3501
	F	Mandays	2.46	324	1.70	209	2.65	245	2.70	461
Bullocks	Hired	–		126		135		329		114
	Owned	–		123		0		0		135
Machines	Hired	–		3547		3333		3129		3806
	Owned	–		103		0		259		104
Seed/Seedlings		kgs	11.26	668	20.65	593	13.54	533	17.96	526
FYM/Organic		kgs	2504	1719	1240	785	2708	1306	943	786
Fertilizers		kgs	195	2610	190	2453	271	2808	165	2720
Micro nutrients		kgs	5	142	2	44	7	138	1	41
PPC		kg/l	6	825	6063	745	5214	1069	10168	728
Irrigation charges		No. of irrigations	16	200	32	200	32	200	64	200
Total cost		Rs.		18515		16552		18,705		17,896
Yield	Main	Qtls	21.39	25856	20.40	24462	20.51	24,957	19.46	24,717
	By	Qtls	12.60	1311	10.45	1163	9.57	1002	13.18	1379
Gross income		Rs.		27167		25,625		25,959		26,096
Net income		Rs.		8652		9073		7254		8200

Source Data collected from surveys

Table 10.6 Per acre costs and returns of Bt cotton

Particulars	Unit	Qty	Value
Hired labour (Male)	Mandays	11.27	2625
Hired labour (Female)	Mandays	21.07	3730
Family labour (Male)	Mandays	4.42	1029
Family labour (Female)	Mandays	2.28	403
Bullocks (Owned)	–		1013
Tractor/Tiller/Machine power (Hired)	–		1367
Tractor/Tiller/Machine power (Owned)	–		620
Seed	kgs	0.83	1636
FYM/Organic	kgs	1498	1774
Bio Fertilizers	kgs	14	337
Fertilizers (Urea+Potash+Complex+DAP)	kgs	184	3365
Micro nutrients	kgs	3	155
Plant protection chemicals (Weedicides, Insecticides, Pesticides)	–	0	1560
Irrigation charges	Acre inch	4.24	1224
Harvesting, threshing, bagging, transportation and marketing	Rs.		175
Total cost	Rs.		21,013
Gross income (Qtls)	Qtl/Acre	8.75	37,822
Net income	Rs.		16,809

Source Data collected from surveys

Drought-tolerant trait in Aerobic Rice The cultivation of aerobic rice in Mandya district started in the year 2011 due to physical and economic scarcity of water. Most of the farmers bought seeds either from university or RSK/KVKs and germination percentage was relatively higher as compared to the seeds purchased from other sources. Over time, the area started increasing since 2011 because of water scarcity. Farmers revealed that high yield and water saving factors induced farmers to adopt aerobic rice.

The modal number of irrigations required in aerobic and conventional rice is presented in Table 10.7. With regard to Kharif, number of irrigations in conventional rice was almost double as compared with aerobic rice. It was estimated that conventional rice required 4500–5000 cubic metres of water, whereas aerobic rice required 1800–2500 cubic metre of water, resulting in water saving to the tune of 50–60% as compared to conventional rice. While in Rabi, amount of water saved in case of aerobic rice cultivation was greater than Kharif grown aerobic rice as seen in Table 10.7.

Bt Cotton Nearly 86% of the Bt cotton sample farmers were cultivating Kanaka Series, Ajitha, Yuva, ATM and US-Agri varieties. All the farmers bought seeds from private agencies and they reported a high germination percentage. The stated area has increased since 2005 because of Bt cotton's resistance to bollworms. High yielding

Table 10.7 Number of irrigations in aerobic and conventional rice

Particulars	Aerobic rice						Conventional rice					
	Mode		Maximum		Minimum		Mode		Maximum		Minimum	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
No. of surface irrigation per week (canal)	2	2	3	3	1	1	2	4	4	4	1	1
No. of ground water irrigation per week	1	1	2	1	1	1	2	3	5	4	2	2
No. of hours per irrigation	2	3	3	3	0.5	2	4	2	6	5	1	2
Discharge of water (in.)	4	2	4	3	1.5	2	2	2	4	4	1.5	1.5

Source Data collected from surveys

and insect resistance are the major factors for adoption of Bt cotton. It is to note that productivity of Bt cotton has been gradually reducing. This concern poses questions on the sustainability of the Bt technology per se as farmers have experienced reduction in yield and income due to infestation of secondary pests in addition to diseases.

Weeds have also been a recurring issue and Bt Cotton farmers have noticed 25 weed species while cultivating Bt cotton in every season. These weeds appeared at all the stages or at any one or two stages. Except those farmers who had noticed Parthenium hysterophorus, no farmers reported yield loss of more than 5%. None of the farmers were applying any weedicide for controlling weeds. Instead, they have adopted summer ploughing and intercultural methods to minimise weeds and incurring a cost of Rs. 1259 per acre for summer ploughing and Rs. 1835 per acre for intercultural operations.

Among the surveyed farmers, 13 pests were noticed while cultivating Bt cotton namely, Aphids, Whitefly, Stem borer, Thrips, Jassids, Bugs, Caterpillar, stem weevil, Leaf miner, Rats, Shoot borer and Leaf hopper as shown in Table 10.8. Most of farmers noticed pests in every season and at various stage of the crop growth. Major pest noticed were Aphids, Mites and Whitefly and to some extent stem borer, Thrips, Jassids, Bugs. However, the yield loss was reported at less than 5%, which was mainly due to the adoption of Bt cotton. Else, the yield loss would have been much higher with the conventional cotton varieties due to persistent bollworm attacks.

In terms of diseases affecting Bt Cotton, farmers reportedly noticed two diseases (Wilt and Leaf curling) and 4 deficiencies, particularly, Magnesium and Nitrogen. However, the yield loss was not more than 5% due to these constraints.

10.3.4 Knowledge and Perception About GM Crops and Willingness to Continue

Knowledge of Farmers regarding GM crops In order to ascertain the extent of knowledge the farmers have regarding GM crops; the farmers were quizzed on these subjects. It can be seen from the Table 10.9 that 24% of the aerobic rice farmers were unaware about GM crops. Nearly 6% of the aerobic rice farmers do not believe that GM crops provide higher yield as compared to conventional crop. Interestingly, no one perceived that GM crops impose an environmental risk.

With regard to Bt cotton farmers, 99% were aware about GM crops and 98% opined an increase in yield as compared to conventional crop. Nearly 20% of the farmers had achieved an increase in yield of more than 20% while and 9% of the households perceived an increase in income to an extent of 20%. About 22% have noticed the difference in quality among Bt and conventional cotton. While only 13% had perceived an environmental risk in cultivation of GM crops due to loss of varietal diversity.

Knowledge of Academicians, Input dealers and Traders about GM Crops The opinions of academicians, input dealers and traders were queried on GM crops and

Table 10.8 Details on pests noticed by farmers

Name of the pest	Reported	Seasonality of occurrence		Severity of incidence			Stages of incidence		Yield loss	
		Every season	Once in a year	Low	Medium	High	All seasons	At any stage	Less than 5%	More than 5%
Aphids	57	57	0	17	9	31	3	54	57	0
Whitefly	67	67	0	14	38	15	0	67	67	0
Stem borer	55	48	7	6	35	14	1	54	52	3
Thrips	68	68	0	43	17	8	1	67	68	0
Jassids	52	52	0	30	12	10	1	51	52	0
Bugs	45	43	2	6	34	4	1	44	44	1
Caterpillar	4	4	0	0	2	2	0	4	3	1
Cotton stem weevil	3	3	0	3	0	0	0	3	3	0
Leaf miner	4	4	0	3	1	0	0	4	4	0
Rats	1	1	0	1	0	0	0	1	1	0
Shoot borer	1	0	1	0	1	0	0	1	1	0
Leaf hopper	2	2	0	0	2	0	0	2	2	0

Source Data collected from surveys
Note Values in the table indicate number of farmers as a per centage to total

Table 10.9 Knowledge of farmers regarding GM crops

Questions	No. of farm HH as a per cent to total	
	Aerobic rice	Bt cotton
Are you aware of genetically modified crop	76.00	99.00
Did Bt cotton give higher yield	–	98.00
Increase yield up to 5%	–	22.00
Increased yield between 5 and 10%	–	34.00
Increased yield between 10 and 15%	–	10.00
Increased yield between 15 and 20%	–	12.00
Above 20%	–	20.00
Did Aerobic rice increase your income	6.00	–
Increase yield up to 5%	36.00	–
Increased yield between 5 and 10%	35.00	–
Increased yield between 10 and 15%	7.00	–
Increased yield between 15 and 20%	11.00	–
Above 20%	9.00	–
Do you find quality difference in GM crop	14.00	22.00
Do you perceive any environmental risk in cultivating GM crop	0	13.00

Source Data collected from surveys

their responses have been presented in Table 10.10. All the 60 respondents know about GM crops and nearly 85% of them have articulated that the GM crop is profitable. While, 62% have opined that GM crop cultivation demands higher inputs and only 13% of the respondents opined that it has harmful effects on human beings.

Table 10.10 Responses of academicians about GM crops

Type of academician	Total	Knowledge about			
		GM crop	Profitability	Higher input requirement	Harmful effects on human beings
Academicians (no.)	20	20	20	7	2
Input dealers (no.)	20	20	15	16	2
Cotton traders (no.)	20	20	16	14	4
Total (no.)	60	60	51	37	8
Percentage to the total	100	100	85	62	13

Source Data collected from surveys

Perception about GM Crops The perception of aerobic rice and Bt cotton farmers on GM Crops has been presented in Table 10.11. Aerobic rice farmers were not keen on cultivating GM crops as only 7% of them agree and only 4% strongly agree with the fact that GM crops are beneficial to them. However, they do consider cost saving advantage as 30% of the farmers agree that GM crops reduces cost of cultivation and 53% strongly agree with this fact.

Bt Cotton farmers are not very averse to cultivation of GM crops as 54% of farmers agree and 14% strongly agree with the fact that GM crops are beneficial to farmers. However, there were farmers who were apprehensive that it may cause harm to human beings, increase in secondary pests and that the benefit may be garnered by large farmers.

Willingness to continue GM Crops The perceptions of willingness of farmers to continue growing aerobic rice and Bt cotton has been presented in Table 10.12. Despite some apprehensions about GM crops, nearly 98% of the aerobic farmers are inclined to continue aerobic rice cultivation and all of them would prefer to continue its cultivation. However, an increase in seed price beyond 25% above the existing price would curtail their willingness. This fact is again reiterated in another question wherein they have mentioned that they would be able to bear a price increase of 1.25 times the existing price. Their willingness to continue also depended on the expectation of an increase in yield level followed by the advantage of GM crops resistance to pest and diseases. Around 80% cotton farmers would drop growing Bt cotton if the seed prices increased by 10–25%.

Health Problems and Precautions Nearly 86% of the aerobic rice farmers applied pesticides by themselves without any precautionary measures resulting in health ailments such as stomach ache, eye and skin irritation. While in the case of Bt cotton, nearly 69% of the Bt Cotton farmers applied pesticides themselves and faced five types of health problems namely Stomach ache, Eye irritation, Skin irritation, General weakness and Fever. They also lost man days apart from expenditure for disease treatment. Some farmers adopted minimum precautionary measures like washing hand/taking bath after applying, not eating or drinking anything while applying. While, wearing boots and spectacles were followed only by a few farmers in the case of both crops (Table 10.13).

10.4 Conclusions

The major findings of the study of 50 aerobic rice and 100 Bt cotton farmers have been presented in the following sub-sections:

Aerobic Rice Age and education were not a limiting factor among the members of the farming community to accept and cultivate aerobic rice. Nevertheless, to some extent, the size of operational holding mattered as aerobic rice was more popular among marginal and small farmers in the study region. In fact, there were no large farmers

Table 10.11 Perception of aerobic rice and Bt cotton farmers about GM Crops

Particulars	No. of aerobic farmers as a per cent to total (50)					No. of Bt cotton farmers as a per cent to total (100)				
	1	2	3	4	5	1	2	3	4	5
Beneficial to farmers	14	54	30	0	2	4	7	1	1	1
Reduce cost of cultivation	24	26	46	0	4	53	30	15	1	0
Ensure food security	14	38	48	0	0	28	24	28	19	0
It may contaminate other crops	0	4	24	72	0	14	7	4	3	1
May cause harm to human beings	0	0	16	80	4	0	1	32	60	1
Food chain will cause health risk	0	2	16	70	12	0	4	33	49	8
Harm agro-diversity	0	4	8	80	8	1	12	28	43	8
Increase monopoly of big companies	2	10	60	26	2	3	8	46	31	4
Involve rigours scientific testing	16	26	48	10	0	0	11	18	23	38
Scientists may hide the harmful effects	4	12	62	18	4	1	8	28	9	2
Large farmers benefit more	2	18	32	36	12	2	7	28	31	21
Cripple indigenous knowledge	8	10	56	26	0	4	6	12	19	48
Foods should be labelled	8	40	46	6	0	16	39	27	5	1
BT information is trustworthy	10	20	66	2	2	3	28	28	22	5
Secondary pests may increase	4	26	18	52	0	0	2	0	0	0

Note Strongly agree = 1; Agree = 2; Somewhat agree = 3; Disagree = 4; Strongly disagree = 5
Source Data collected from surveys

Table 10.12 Willingness of farmers to continue growing aerobic rice and Bt cotton

Particulars		No. of aerobic farmers as percent to total (50)	No. of Bt cotton farmers as percent to total (100)
Willing to pay for new variety		98	99
Percent of additional price prepared to pay for desired trait	Less than 10%	28.57	34
	10–25%	55.11	36
	25–50%	16.32	20
	Above 50%	0	9
Other traits preferred in new variety	High yielding	60	42
	Resistant to pest and diseases	40	31
	Drought resistant	6	21
	Medium straw length	6	–
	Easy picking	–	5
	Good quality	36	100
What price should be fixed for GM crops	No change	16	6
	1.25 time more than existing	60	41
	1.50 times more than existing	24	33
	Double the existing price	0	20

Source Data collected from surveys

in sample size. Majority of the farmers who had adopted aerobic rice have decades of experience in cultivation of conventional rice. Their experience in cultivation of aerobic rice was around 2 years as aerobic rice was a recent introduction and the productivity have remained constant at 21–22 Qtls per acre for the last two years. With regard to cost of cultivation of aerobic rice, farmers had obtained slightly higher productivity than conventional rice leading to higher gross returns. Yet, the net return from aerobic rice was lower less than conventional rice as the cost of cultivating aerobic rice was higher by 10–12% in comparison to conventional rice during both, Kharif and Rabi. The expenditure on labour was highest among other expenses.

In terms of traits, the drought tolerance trait of aerobic rice was amply visible in terms of water saving. The inputs like seeds, fertilizers, plant protection chemicals were not applied as per the recommendations. This resulted in increased cost of cultivation, and also had negative effect on the yield. This aspect could be related to the fact that around a 25% of the aerobic rice farmers did not have any knowledge about GM crop. However, they were willing to continue aerobic rice even at increased seed cost. Very high per cent of aerobic rice farmers perceived and agreed that GM crops are beneficial to farmers. Many of them also felt that the cost of cultivation of aerobic rice is higher than conventional one. The farmers had mixed views on

Table 10.13 Health problems faced by aerobic and Bt cotton farmers due to application of PPCs

Health problem	Aerobic Rice			Bt cotton		
	No. of households faced (as a per cent to total sample)	Average man days lost due to health problem	Expenditure incurred towards medicines and other related expenses (Rs.)	No. of households faced (as a per cent to total sample)	Average man days lost due to health problem	Expenditure incurred towards medicines and other related expenses (Rs.)
Stomach ache	2	6	126.66	8	1.75	1328
Eye irritation	8	2.5	85.83	16	3.06	1113
Skin irritation	4	2.8	188.33	11	2.45	905
General weakness	–	–	–	14	3.57	1308
Fever	–	–	–	4	2.75	1205

Source Data collected from surveys

issues such as negative impact on humans and agro-diversity. Aerobic rice farmers perceived that Ragi is more profitable crop than aerobic rice. It can be inferred that farmers were not out-rightly rejecting to cultivate aerobic rice and have been finding ways and means to efficiently and effectively cultivate taking technological advises from available sources.

Bt Cotton The important indication of the study was that age and education are not a limiting factor to accept and cultivate Bt Cotton. Nevertheless, small and medium farmers had taken more interest in cultivating Bt Cotton than marginal and large farmers. The sample farmers were cultivating Bt Cotton since 2005. Labour cost accounted for the highest among all other items under cost of cultivation. The insect's resistance (IR) trait of Bt Cotton was not fully realised as the fields of Bt Cotton did not get rid of insects. The inputs like seeds, fertilizers, plant protection chemicals were not applied as per the recommendations. This led to increased cost of cultivation, as well as had negative effect on the yield.

Almost all the Bt cotton farmers were aware about GM crops and they were willing to continue cultivating this crop. These farmers firmly believed that GM crops bring down the cultivation cost. However, they had mixed views on issues such as negative impact on human health and agro-diversity. An apprehension expressed by Bt cotton farmers was that the IR trait of Bt Cotton resulted in damaging other crops as the cotton insects had adapted themselves to other crops.

Overall, it can be concluded that the sample farmers do not categorically reject the cultivation of either Bt cotton or aerobic rice. They have been looking for means for changing from one variety to other, while taking technological advises from available sources. Therefore, dissemination of proper and credible knowledge about GM crops through robust extension services would help in convincing the farming community to adopt GM crops in lieu of conventional crops. This should be offered to farmers as a package. In addition, concurrent assessment of the implemented package for GM crop is essential for sustenance of the technology through suitable intervention.

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Part III
Conclusion

Chapter 11
Frameworks and Guidelines for Socio-economic Assessment

Sachin Chaturvedi, Krishna Ravi Srinivas and Amit Kumar

Abstract The most important challenge in Socio-Economic Assessment (SEA) lies in developing suitable frameworks and guidelines that can be implemented. As many factors and values have to be considered in any such assessment, inevitably issues on methodologies and approaches have to be addressed. Since SE Assessment goes beyond traditional economic assessment including Cost–Benefit Analysis, any discussion on SEA will also be a discussion on alternative frameworks, methodologies and bringing together economic factors and non-economic factors. This chapter discusses the approaches explained in the literature to estimate the various impacts and what costs and factors are considered in different methodologies.

Keywords Socio-economic assessment (SEA) · Impact assessment · SEA methodologies · Guidelines framework · GM crops

11.1 Introduction

There are many approaches and methodologies for conducting Socio-Economic Assessment (SEA). Impact assessment of technologies and projects is nothing new. They can be comprehensive or depending upon the need assessment can be on the basis of selected parameters or assess the impacts for few issues like impact in terms of economic gain, impact on environment and impact on communities. These impact analyses are to be used for decision making. Article 26.1 acts as a guiding article, and should be read with the overall objective of CPB in mind.

A SEA can be conducted at different stages in the life cycle of a LMO or a comprehensive SEA can be made part of assessment of LMO. Fundamentally an

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ideal SEA will have qualitative and quantative analysis and will give a comprehensive picture that will help in decision making. But to decide on commercialization of a LMO or permission for wider use, a SEA can be part of decision-making and in such cases, regulations often specify what a SEA should cover or consider. So it is important that SEA methodologies are theoretically robust and are not technology- or application-specific while being sensitive to specificities of technologies. In this chapter we look into issues on SEA and how various methodologies have been used in SEAs.

SEA is not unique to the Protocol. Some other conventions and protocols have provisions for such SEAs and guidelines are developed for use by Parties. For example UNEP prepared a guidance document for SEA under Stockholm Convention on Persistent Organic Pollutants, in 2007 and it was revised in 2017. This is meant to aid developing national implementation of the Convention (UNEP 2017). A typical SEA of chemicals is shown below. SEA in this case considers, broadly impacts on health, impact on the environment and impact on economic development. The impacts are caused by pollution. In other words SEA in this case estimates the impacts of the chemicals by studying how pollution impacts health, environment and the economic impact. The economic impact will include, inter alia, the costs incurred to offset/reduce pollution, costs incurred to remedy the negative impacts on account of pollution (Fig. 11.1).

Often SEAs are prepared as part of national strategies or plans in environmental governance norms and in resource use planning. Some assessments go beyond SEA and explicitly are titled as Socio-Economic and Environmental Assessment (SEEA). For example see GUIDELINES FOR SOCIO-ECONOMIC AND ENVIRONMENTAL ASSESSMENT (SEEA) Land Use Planning and Resource Management Planning issued by Government of British Columbia.[1]

In the last decade or so, such assessments have been extended to different sectors, from mining sector to assessing the SE impacts of egovernance projects and in assessing impacts of production of bio-energy (Rutz & Janssen 2014). While some factors may be common as most assessments include economic impacts/benefit, a context based approach is used as although the idea to have a SEA is relevant and widely accepted, often what matters most are the objectives such assessments and how they are perceived by different stakeholders. It can be pointed out that SEA can be helpful in deciding on Social License to Operate (SLO), although this view may be controversial.[2]

In this chapter while we discuss frameworks and guidelines for SEA it is obvious that there is no last word in the subject. The frameworks and guidelines will evolve further and hence only suggestions can be made on them than taking a position that this is the ideal framework and guideline and recommending it as the best solution to give effect to Article 26. As Chap. 2 and Chaps. 3, 4, 5, 6, 7, 8, 9 and 10 also

[1]https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-resource-use/land-water-use/crown-land/land-use-plans-and-objectives/policies-guides/seea_guidelines_lup_rmp.pdf.

[2]On SLOs see van Putten et al. (2018).

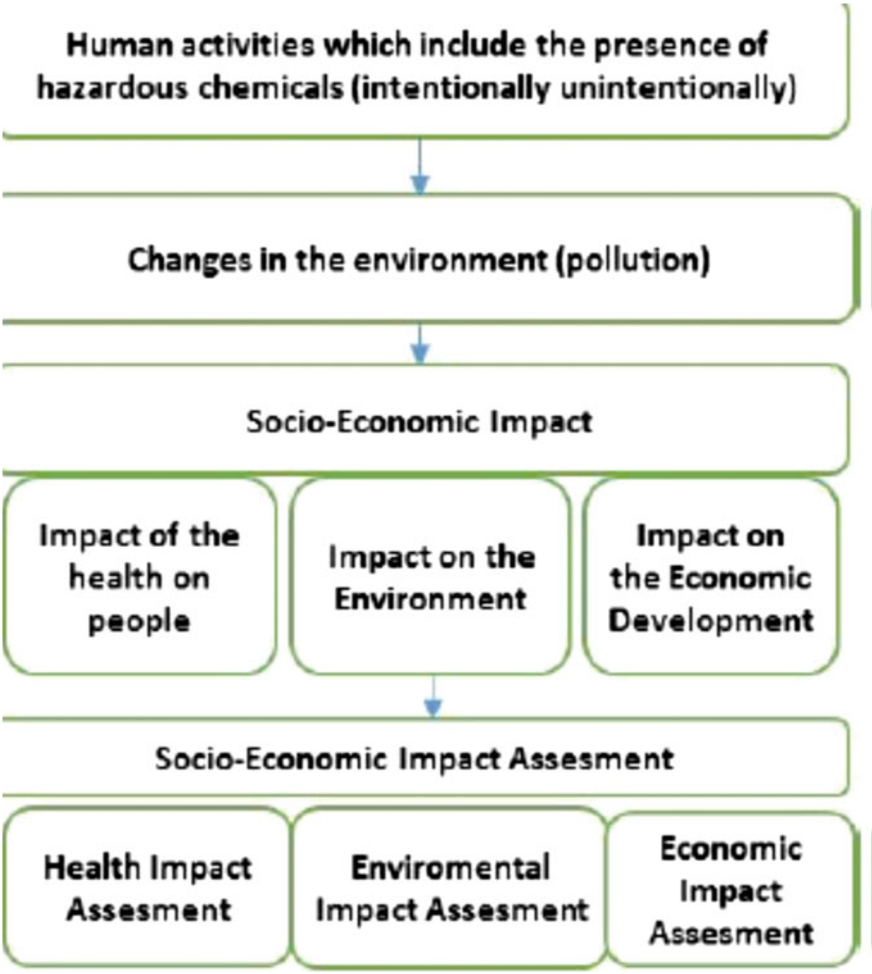

Fig. 11.1 Socio-economic assessment of chemicals. *Source* Brnjaš et al. (2015)

deal with different aspects of SEA including methodologies for assessing economic impacts, cost–benefit analysis and analysis of risk perception and collecting data on stakeholder perspective it is suggested that the readers should treat this chapter as part of the narrative that flows across this volume, than as a stand alone chapter.

11.2 Impact Assessment: Methods and Contexts

Ex ante or *ex post* approaches are used extensively in impact assessment of interventions in agriculture such as introduction of new technologies, introduction of new varieties or changes in uses of resources and inputs. *Ex ante* studies are done to estimate the potential impacts of an innovation after its adoption or diffusion. So *ex ante* studies can be done at different periods of time, post adoption. Since we are discussing SEA in the context of agriculture, particularly crops, we focus on relevant issues and methodologies in this chapter.

While studies conducted at micro level or farm level are very necessary they are not sufficient enough to give a comprehensive assessment. So often, meta analyses of various such studies are done by scholars to analyze and synthesize so that some broad general conclusions can be arrived at, often with caveats or explaining the merits and shortcomings in such studies. They help in identifying the issues for further studies. While meta-analysis is necessary for a decision maker their findings cannot be the only source to decide. Macro-level studies indicate the impact at the national or regional levels, while sectoral studies indicate the impact at the level of sectors such as market and are conducted to assess broader impacts on related sectors such as trade, investment and economic growth. To begin with a baseline scenario and an impact scenario are required to be prepared to carry out the impact assessment of LMO cultivation using indicators such as yield enhancement. Baseline scenario is the situation in which there is no LMO cultivation or use, whereas impact scenario implies a situation in which LMO cultivation is undertaken or LMO is adopted or used. Impact measured in terms of an indicator is:

$$Impact = value\ of\ indicator\ in\ impact\ scenario - value\ of\ indicator\ in\ baseline\ scenario$$

Baseline scenario can be estimated by using primary or available data while impact scenario can either be *ex ante* or *ex post*. Data collection from adopters and non-adopters can be used for impact assessment. Generally farmers do not switch over to a new crop or variety in one go and tend to experiment with new while still using the old by allocating different areas for them. Base line data can be prepared taking into account data from the past. It is suggested that while preparing base line scenario data from last few years are taken into account and a long-term view is also taken to ensure that the scenario gives a true picture. For example while total area under cultivation in a region may remain constant, there can be changes in areas under cultivation for different crops and also areas cultivated in different seasons or cropping cycles.

In case of yet to be commercialized LMOs, data collected from field trials can be used for carrying-out ex *ante* studies. However, as they are controlled field experiments, which might be different than the actual farming, there is a need to be cautious while using them. Primary data is by far a more reliable source. As farmers tend to have long farming experience before switching over, data prior to switching over can be compared with data after switching over. As SEA itself can be a long-term exercise it is important to consider this.

Many models are applied for carrying out economic impact analysis at different stages. The common approaches used for the purpose are shown in Table 11.1.

For assessing welfare gains from introducing a technology, economic surplus models have been used in many studies. In such exercises, Benefit-Cost Ratio, Net

Table 11.1 Approaches for socio-economic assessment

	Approaches	Ex ante	Ex post
Micro	Adoption	Simulation	Logit/probit, tobit, heckman, double hurdle
	Impact	Simulation, ex ante economic surplus analysis	R a n d o m i z e d C o n to l T r a i l (R C T), P S M (Propensity Score Matching), DD (Double Difference), Instrumental variable (IV)
Macro	Adoption	Systematic review, simulation	Systematic review
	Impact	Systematic review, economic surplus using model using DREAM model	Systematic review

Source Chapter 9 in this book

Present Value (NPV) and Internal Rate of Return (IRR) are generally used to assess the gain. These are used to assess the difference a technology could make in terms of welfare to stakeholders, in this case farmers. Among farmers too, the gains need not be uniform, in fact often they vary widely.

Partial equilibrium models are used for assessing the distribution of costs and benefits among inter alia, producers, consumers, using indicators such as producer and consumer surplus. Computable General Equilibrium (CGE) models are used to study broader impacts such as cross-sectoral ones. They provide comprehensive and better inferences.

Ex ante assessments are used to estimate the impacts of various scenarios associated with change in inputs, costs, outputs and yield. Scenario analysis are used to estimate the welfare effects of various technological interventions. These are necessary as yields vary depending on parameters. For example, an increase in input cost without a corresponding increase in yield can diminish the welfare effects of adoption. For policy makers to design policies to promote adoption such inferences are important.

Scenario analysis can help in identifying potential impacts of different policies and hence can help in taking appropriate actions. "Dynamic Research Evaluation for Management (DREAM)" is a software that is useful to measure economic surplus, as the *ex ante* model generates aggregates of economic consequences, with the introduction of a technology or without it, in single or multiple markets.

Availability and quality of data can make an impact on using models to assess economic impacts. Primary data is usually necessary for an *ex ante* assessment, while *ex post* assessment can be carried out using secondary data. Though, for many parameters, in *ex post* assessment, primary data is also needed. While using secondary data in *ex post* or *ex ante* assessments, careful attention should be given to comparability of data across studies, impacts studied, models used, and the data collected period. Therefore, reliance of secondary data should be considered with an understanding of its inherent limitations, while undertaking a meta or *ex post* or *ex ante* analysis.

Since the impacts may change over a period of time, any economic impact study on cultivation of LMOs (whether *ex post* or *ex ante*) can be done within a specified time period. For better result, the assessments should cover at least two cropping seasons or one year. In fact they should be done for a longer period to get a better idea.

Studies on the economic impacts of LMOs have a significant share the available literature on LMOs in India. The reason is obvious. Bt cotton that has been studied the most in India as it is the only LMO approved for cultivation. Another factor that favors study of Bt cotton is that the availability of long-term data on cultivation of cotton across different regions. Over a long period there had been significant changes in cotton cultivation and adoption by farmers, of different technological options. In terms of varieties and inputs there have been significant shifts. But the rapid adoption of Bt cotton has been studied extensively and farmers switching over to Bt cotton despite higher spending for inputs has also been investigated. Economists have been successful in explaining the rationale behind such adoption. Meta analyses have concluded that there have been significant economic gains of using Bt Cotton. However, there is no consensus on whether the economic gains could be solely attributed to the trait. As this has been discussed in Chap. 1 we will not belabor the points here. Globally also this issue has resonated.

According to a report from National Academy of Sciences (NAS),

> To assess whether and how much current and future GE traits themselves contribute to overall farm yield changes, research should be conducted that isolates effects of the diverse environmental and genetic factors that contribute to yield. In future experimental survey studies that compare crop varieties with Bt traits and those varieties without the traits, it is important to assess how much of the difference in yield is due to decreased insect damage and how much may be due to other biological or social factors. (p. 27). NAS (2016)

Many methods have been used in economic impact assessment of LMOs and the impact at different levels viz. micro, macro, sectors, across-sectors and temporal has been studied (Table 11.2). These methods are necessary to get valuable guidance in understanding the impacts of various technological interventions or policies and at different levels and sectors.

11.3 Towards Comprehensive Socio-economic Assessment

To assess the overall socio-economic impacts of LMOs, economic impact studies are necessary but not sufficient. Socio-economic assessment is very much required as many studies have revealed that technologies are not scale neutral, gender neutral and they impact different stakeholders differently. There are also issues like, unanticipated and unintended consequences arise (such as negative environmental impact, increase in pest resistance) and as the economic gains tend to vary significantly, across regions and over years, economic impact assessment alone cannot be used to justify permission to use or to promote adoption. Non-economic variables such as access to proper information and knowledge, risk perception and availability of support from technology providers/government, influence the adoption of a technology,

Table 11.2 Common approaches for assessing the impact of biotechnology applications

Level	Scope	Impact evaluated	Indicators used	Time frame	Approach/ model
Micro	Farm (family village)	Agronomic	Yield, cost of production factors	Ex ante	Effects on production function
				Ex post	
		Socio-economic	Workload, family income, health of workers, additional time	Ex ante	Household approach
				Ex post	
Sector	Market of a single product in a single country	Economic	BCR	Ex ante	Dynamic Research Evaluation for Management (DREAM)
			Internal rate of return		Scenario analysis
			Net present value	Ex post	Aggregate economic welfare analysis (single market partial equilibrium models)
			Distribution of benefits between operators of the production chain		Economic surplus models
Macro	Market of many products in a single country Market of a single product in many countries multicommodity market in many countries	Economic	International price of products	Ex ante	Partial equilibrium models (few commodities) Computable general equilibrium (CGE) models (across commodities and sectors) (DREAM) multimarket analysis
			Distribution of benefits between regions or countries (adopters/non-adopters)		
			Distribution of benefits between society categories	Ex post	

Source FAO (2009), p. 6

across various groups and for decision making, risk perception, expected gains and anticipated impacts on health and environment are important.

A comprehensive approach on rural development and livelihoods is *Sustainable Livelihoods Approach (SLA)*: SLA has been used extensively by agencies like DFID and FAO. SLA examines the various livelihood assets, livelihood strategies and outcomes and it can be done at the level of a family and at the level of a village. The main advantage in SLA is it takes into account the impacts on livelihoods than just on economic gains/losses and can be used to assess what would adoption of a LMO mean to farmer or her/his family. It can incorporate quantitative elements and qualitative aspects. Insights from SLA can provide a better understanding of socio-economic impacts although SLA per se cannot be considered as a SEA that would be suitable for decision making as mentioned in Article 26. Thus SLA can be part of the exercise to conduct SEA. The foci on livelihoods and different types of capital can help in examining alternative pathways and potential impacts of varying degrees or levels of adoption. At the same time as the objective of SLA is to contribute processes and policies that makes livelihoods of farmers and farming communities more sustainable and resilient, the research methodology and design of study has to be understood before using findings from SLA for SEA. In the literature there is hardly any direct study on using SLA to assess impacts of LMOs or genetically modified crops although it seems that some steps were taken to examine use of SLA in the context of agricultural biotechnology (Falck-Zepeda et al. 2002) (See also Ludlow et al. (2014)).

A typical SLA framework is given below (Fig. 11.2).

Environmental Impact Assessment (EIA): Given the concerns on environmental impacts of LMOs incorporating EIA in SEA is essential. However what aspects should be considered is a difficult question because only a suggested list can be given. Temporal dimension is also important. Generally crops are assessed before

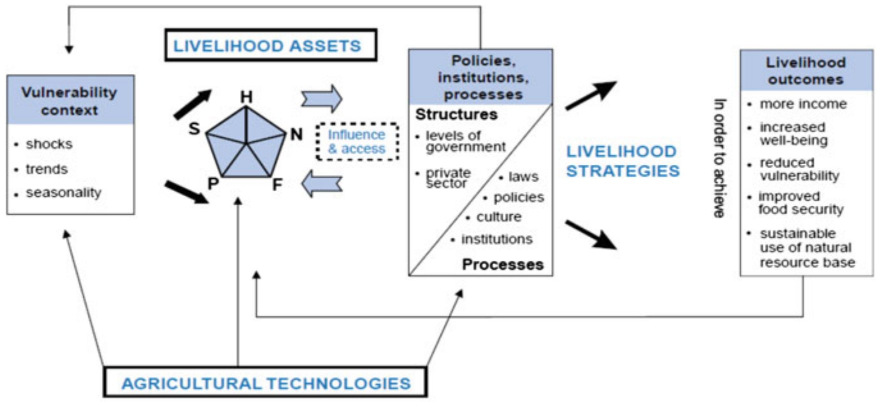

Fig. 11.2 Typical SLA framework. *Source* Meinzen-Dick (2001)

adoption for a shorter term while long-term studies on environmental impacts may be ideal. In respect of LMOs, concerns on gene transfer to wild relatives SEA should include the assessment of LMOs on biodiversity, given the importance of biodiversity conservation and sustainable use in CPB. The impacts could be in terms of direct ones such as gene transfer to wild relatives, gene transfer to conventional crops, potential for inducing weediness, effects on non-target organisms, changes in the soil quality and impact on water quality. There are many studies on them and the NAS report provides an excellent summary. However it needs to be understood that EIA being context specific has to be done taking into account the novelty of the trait/feature and the different ecosystems or agro zones where the LMO/GMO will be adopted. While field trials provide enough evidence and data, EIA as part of SEA can go beyond them. It can examine issues not addressed in the field trials, and, can adopt a different methodology. As CPB and CBD are concerned about impacts on indigenous communities and their practices, EIA for SEA can be done specifically to assess impacts in regions where these communities' practice, particularly traditional agriculture.

Outcrossing potential among crops is an issue particularly in countries that are rich in biodiversity with species that are endemic to particular regions. So assessing the potential for outcrossing among GM crops and flora found in region/country is important.[3] This can help in decision making and in regulating cultivation. In India, the taskforce headed by M. S. Swaminathan recommended that "important centres of origin and diversity should be protected so as conserving precious agro-biodiversity in their pristine purity". Moreover it recommended that in agro-biodiversity sanctuaries, on lines of, wildlife sanctuaries and national parks, "the cultivation of GM crops should be prohibited". Another recommendation of the task force was regions that are centres of rich biodiversity should be free from cultivation of GM crops, "until more data are available on the long-term impact of the introgression of transgenic material into native biodiversity".

During the field trials, some of these are assessed and since they conducted on selected sites for experimental purposes, the data from such studied cannot be extrapolated as if they represent the real farm conditions in all regions. Given the variations in biodiversity, pests and weeds across regions a study has to consider data from many regions. Although long-term studies are preferable undertaking them in selected areas/regions is preferred. Thus for approval for cultivation and adoption short term studies are done and results are analyzed as to examine whether any adverse environmental impacts are found. Conditional approval is also possible. For example, in case of GM crops it is often mandated that a particular percentage of area under cultivation should be left for non-GM varieties as refuge. In the literature by and large, studies indicate that positive environmental impacts outweigh the negative one and some of the fears such as development of super weeds are exaggerated.

[3]See Sanchez et al. (2016) for an example of such an analysis.

Brooks and Barfoot (2015) highlighted the positive environmental impacts of GM crops measured in terms of reduction in pesticide use and argue

> The adoption of GM insect resistant and herbicide tolerant technology has reduced pesticide spraying by 553 million kg (8.6%) and, as a result, decreased the environmental impact associated with herbicide and insecticide use on these crops (as measured by the indicator the Environmental Impact Quotient (EIQ)) by 19.1%. The technology has also facilitated important cuts in fuel use and tillage changes, resulting in a significant reduction in the release of greenhouse gas emissions from the GM cropping area. In 2013, this was equivalent to removing 12.4 million cars from the roads.

Many studies have found that the use of LMOs has reduced the use of herbicide and insecticide and there by have made a positive contribution. According to a report from NAS, the evidence is mixed but there is little evidence to link GE crops with adverse agronomic or environmental problems (NAS 2016, p. 99). It also pointed out that usage of pesticides in terms of kgs, does not necessarily predict environmental effects. It should also be pointed out that the evidence of gene transfer to wild relatives has been lacking, despite the fears about it.

Studies have to be conceived and carried out, taking into account the new trait and its impact on quantity and quality of chemical usage, and the estimated impact on target organisms. As pointed by NAS report and other studies, there is not any evidence of linking LMOs with any harm or reduction in biodiversity so far. However, it should be bear in mind that the issues of displacement of traditional varieties and cultivars and the impact on in situ conservation do not get overlooked or neglected.

11.4 Methodologies for SEA

Methodologies for SEA can be prepared on the basis of approaches to SEA. But so far there has been no consensus what should be considered as key elements for Socio-Economic Considerations (SEC). As explained elsewhere in this volume countries have interpreted and implemented Article 26.1 in many ways. While the AHTEG and the discussions have highlighted some key elements in SEC there is no consensus.

According to The Netherlands Commission on Genetic Modification (COGEM), any SEA framework should take into account the following:

- Quantitative and qualitative effects
- Reversible and Irreversible effects
- Distribution of effects
- Uncertainties with regard to effects
- The possibilities and limitations of ex ante or ex post studies
- The possibilities and limitations of various types of analyses
- Value to society.

Further COGEM has identified the following as building blocks for assessing the impacts of LMOs:

- Economy and Prosperity
- Health and Welfare
- Food Supply and Food Security
- Cultural Heritage
- Freedom of Choice and Co-Existence
- Safety
- Biodiversity
- Environmental Quality.

One issue with such "building blocks" is that they are hard to define or measure and could mean different things to different stakeholders. Which among them should be prioritised or should all be assigned as equally important is an issue. In case of freedom of choice, how to consider the question of choice from perspectives of different stakeholders? Does it include freedom to cultivate/consume GM crops even when a majority of farmers and consumers are against it. In case of food supply and food security GM crops can make a positive difference and will that be considered as a primary reason to approve them. Of these, safety is taken care by the risk analysis while cultural heritage is not a relevant factor in most instances. While biodiversity and environmental quality are important, assessing the impacts has to be done on the basis of credible and accepted scientific practices. Regarding freedom of choice and co-existence these are issues that could have different meanings in different countries. Health and welfare are certainly important and including welfare in SEA is problematic.

Interestingly, COGEM states "*The rejection of GM crop on the basis of arguments other than safety, while these arguments will apply the same extent to conventional crops that are not subject to these criteria could be seen as (unjustly) creating an uneven playing field*". (COGEM 2014, p. 29). Hence SEA should have credibility and legitimacy and should not be seen as an exercise that is inherently biased against LMOs.

COGEM and most of the suggestions from Europe on SEA is that they tend to expand the scope of SEA; making the process more complex by including values and norms that are difficult to measure t With respect to food supply and food security, assessing the impacts of LMO cultivation on food supply can be assessed vis a vis the cultivation of non-GM crops. Hence, food supply when considered in quantitative terms is acceptable as an indicator in SEA. But food security is a complex subject and distributional and matters on access to food are equally important. Often these have little to do with technology and more to do with other factors. So incorporating them in SEA should be done with caution.

Although the reports of AHTEG and COGEM have helped in identifying the key elements for SEA, the contextual understanding is crucial for conducting SEA. For example, while co-existence of LMO and non-LMO are issues in Europe but it is not so in India. A contextual understanding will include the value of traditional varieties in culture and economy.

While conducting SEA at the national level, the key elements have to be identified and ranked in terms of their importance, if such a ranking is desirable or mandated.

Irrespective of other elements it is essential that SEA considers biodiversity conservation and use and impacts on traditional/indigenous communities to reflect the concerns expressed in CBD and CPB. Thus that can be the starting point in any exercise on SEA.

11.5 Guidelines Framework for Socio-economic Assessment

Based on an extensive analysis of literature, CDB discussions, experts' consultations and field surveys, we propose a guidelines framework for the SEA. We have identified 11 key objectives to be part of this guidelines framework.

This guidelines framework is only indicative and is an example. Although farmers may be considered as a single category of stakeholders as the impact on small and medium farmers varies from that of large farmers, we have listed them as separate categories. It is important to assess the net gain vis-a-vis the net gain from cultivation of conventional, i.e., non-LMO crop or variety, for such farmers. Whether the net gain is commensurate with the increase in cost of inputs and whether that is good enough for them to switch over to or opt for LMOs has to be assessed.

Studies on impact on labor have shown that in case of *Bt* cotton the demand for labor including women labor increased in order to carry out the operations such as picking and the demand for labor for spraying got reduced as the number of sprays and quantity sprayed were lesser than that of the conventional crops.[4] Thus it is important to assess the overall impact on labor, in terms of earnings, cost, and health impacts. Literature shows that herbicide tolerant (Ht) LMOs are likely to reduce the demand for labor, as labor needed for weeding might get reduced. In that case, the income lost on account of reduced demand for women labor on account of weeding vis-a-vis the positive impacts on them in terms of health has to be estimated so that the assessment is comprehensive. However it is not as simple as it looks as demand for labor and supply depend on many factors, including wages and alternative options for both farmers and laborers.

To develop a guideline framework we have prepared a set of objectives and corresponding principles. From the literature and studies in other chapters we have assembled 11 key objectives and they are described in the Table 11.3.

Broadly speaking, there are five key dimensions that are important in a socio-economic assessment. Hence data on them is essential for conducting any meaningful SEA.

The five key dimensions are

I. Economic
II. Health

[4] In fact there are not many studies that look into gender dimension in adoption of LMOs. A much cited study (Subramanian et al. 2010) shows that cultivation of Bt crops has positive impacts on women's employment.'

Table 11.3 Guideline framework for socio-economic assessment

Sl. no.	Objectives	Variables/Parameters	Principles	Methodology
1	Assessing increase in yield/ productivity in LMO crops that have yield-determinant traits	Yield gain (kg/ha); yield gain (reduction in crop damage from pest/insect infestation)	Increase in yield per hectare; yield gain due to reduction in crop damage from pest/insect infestation	Partial Equilibrium; Linear Regression; multi stage stratified random sampling; Cobb-Douglas Production Function; Economic Surplus Model (for *ex ante* Studies)
2	Assessing the reduction in use of pesticide in LMO crops that have pest tolerating trait gene(s)	Pesticide quantity use frequency of pesticide use residues of pesticides in output/soil samples		Partial Equilibrium; Linear Regression; multi stage stratified random sampling; Cobb-Douglas Production Function; Economic Surplus Model (for *ex ante* Studies)
3	Assessing health benefits of farming families and farm labor force	Health check-ups; medicines; sickness and loss of days/loss in earnings Effects of changes in residues of pesticides in output/soil samples	Decrease in ailments measured through reduction in duration of sickness, reduction in expenditure on medicine/treatment for such ailments;	Partial Equilibrium; Linear Regression; Multi Stage stratified random sampling; Cobb-Douglas Production Function; Economic Surplus Model (for *ex ante* Studies)
4	Analyze economic gains for farmers	Pesticide cost; labor cost (used for spraying and weeding) Fertilizer cost Irrigation cost Medicines cost (These are costs that the grower would have incurred had s/he not opted for LMO with the trait(s))	Less investment in buying insecticides, Less labor cost per season; fertilizer; Changes in irrigation and medicines costs	Partial Equilibrium; linear regression; multi stage stratified random sampling; Cobb-Douglas Production Function; Economic Surplus Model (for *ex ante* Studies)

(continued)

Table 11.3 (continued)

Sl. no.	Objectives	Variables/Parameters	Principles	Methodology
5	Assessing consumer benefits	Product price; Safe product due to less risk due to harmful chemical residues	Reduced cost and Safer products	Partial Equilibrium; linear regression; multi stage stratified random sampling; Cobb-Douglas Production Function; Economic Surplus Model (for e x-an te Studies) Survey
6	Assessing impact of seed prices on overall costs and changes in yield	Seed cost comparison; willingness to pay Value addition on account of trait Value in terms of life of the new LMO technology	Variable claims for seed cost difference Cost difference versus changes in gains and savings Value for farmer from the trait/seed Seed saving/reuse rate and changes in costs	Partial Equilibrium; Linear Regression; Multi Stage stratified random sampling; Cobb-Douglas Production Function; Economic Surplus Model (for ex ante Studies)
7	Assessing economic gains for small and medium farmers	Net gain on account of savings in costs and increase in yield versus increase in seed cost and additional cost of increased use of major inputs (fertilisers, irrigation, agro-chemicals) and other factors	Comparing with non- GM varieties, cost-benefit analysis	Partial equilibrium; linear regression; multi stage stratified random sampling; Cobb-Douglas Production Function; Economic Surplus Model (for ex ante Studies)

(continued)

Table 11.3 (continued)

Sl. no.	Objectives	Variables/Parameters	Principles	Methodology
8	Assessing long-term gains for farmers	Increase in returns over a period, sustaining the increase and gains Impact on factor productivity in the relevant cropping system. This can be assessed if relevant methodologies are available and reliable base line data is also available	Long-term cost-benefit analysis	Longitudinal studies; survey
9	Assessing environmental benefits	Residues of toxic pesticide in environment; reduction in use of pesticides	Soil quality, residues of toxics in output, reduction in use of pesticides over a period	Testing soil samples and outputs' changes in types of pesticides used; measuring impacts on humans and non-humans
10	Assessing impact on labor (from perspective of labor)	Employment (Man days)/Economic Loss of the commodity	Less labor used for insecticide spraying or weeding purpose and income loss; cost of labor versus income in other options for labor	Survey; employment pattern and income; labor usage time and income; changes in employment and costs/benefits
11	Assessing impact on women (from women labors/farm labor perspective)	Employment (days of work); income; income from non-farm activity/other options	Quantum of womens' labor in terms of days/hours for different tasks; reduction in wages; wages in non-farm labor activity;	Survey; employment pattern and income; labor usage time and income; changes in employment and costs/benefits

Source Author's own compilation

III. Environmental
IV. Social
V. Cultural.

11.5.1 Economic Dimension

(1) This potential of LMO is tested in experiments and field trials. Based on the yield, its performance vis-a-vis potential is assessed. To assess it in real world conditions for evaluation and to check whether the potential is realized and if so to what extent, is obviously important. The parameter here is yield gain. This can be due to the trait conferred to the LMO which enhances productivity or due to better seed or reduced damage from pests.

(2) The yield gain should result in income gain for the farmer. The gain from the LMO can be compared with income from non-LMO.
Income = Price × Quantity. The same formula should be applicable for non-LMO. If the yield gain is not translated into commensurate income gain, farmers may not gain much from adoption.

(3) We need to assess the cost incurred on account of adoption of LMO, for the farmer or for the region and evaluate whether the economic and social gains are adequate enough to justify costs incurred. The costs incurred are
Seed, agro-chemicals (fertilizer, pesticides, etc., as the case may be), feed/fodder in case of animals, water, energy, labor, implements, machinery, depreciation of equipment, interest on loans, insurance, if any. These costs are commonly incurred costs. If the adoption of LMO demands extra costs or other costs not listed here they should be taken into account.
For arriving at the costs there are standard methods and these have been codified by ICAR for economic assessment of costs of cultivation. We suggest that these methods be used to estimate the costs.

(4) Net benefit to the farmer is to be estimated. This the difference between income and costs, i.e., income – costs. Further the costs can be bifurcated into fixed and variable costs. Here also standard methods are used to identify and arrive at fixed and variable costs. There are no suggested methodologies here as this is a simple formula and can be used to arrive at the net benefit to the farmer.
The net benefit from adoption should obviously be more than the net benefit from non-LMO. A comparative analysis of net benefit from LMO versus non-LMO can indicate whether it is economically beneficial to society or whether farmers will adopt it.
The above parameters thus measure the impact on farmers in terms of gains in yield, income and whether adoption results in economic gains to producers. The preferred or optimal gain for deciding the suitability of LMO for approval is set by regulator. ICAR in evaluation and approval for cultivation stipulates a

minimum increase in yield. Yield gains do not necessarily translate into corresponding economic gains. But SEA need not go into greater details on this.

(5) Assessing economic gains for small and medium farmers: To estimate the impact on small and medium farmers, net gain on account of savings in costs and increase in yield versus increase in seed cost and additional cost of increased use of major inputs (fertilisers, irrigation and other costs) has to be calculated. Comparing non-LMO varieties with LMO varieties in respect of these costs and the associated gain can be used. Cost-Benefit analysis can also be used.

(6) Assessing long-term gains for farmers is important as the gains from LMO should be consistent and sustainable. As adoption may entail more investments and increase in costs, unless the LMO provides sustainable additions to incomes it may not be preferred by farmers.
Given the investment required from farmers for adoption the long-term gains should be commensurate with that and farmers should get gain over a long period without wide variations in yield, income and net gain. For decision making, assessing the increase in returns over a period, and the sustainability of the increase and gains and the impact on factor productivity in the relevant cropping system. This can be assessed if relevant methodologies are available and reliable base line data is also available.

(7) Consumer Benefit: Increase in availability at a lower cost is the parameter to assess consumer benefit. For consumer, unless the economic or other gains are not translated in terms of cost or availability, no direct benefit is derived from LMO. As demand is sensitive to price, lower price can stimulate higher demand from consumers. But when the supply increases without any change in price it may indicate that there are no direct economic gains for the consumer while the producer has gained on account of reduction in cost and increase in yield.
So the regulator needs to assess the impact on consumers who as a category are different from producers. In this the regulator can assess how different types of consumers are impacted by LMO and whether some consumers benefit more than others. So even when there are net gains for consumers, the regulator may want to know as to which type of consumer benefits the most and who benefits the least. Hence for this additional data or information may be sought.

11.5.2 Health Dimension

(1) The health impacts have to be assessed as part of SE assessment. While at the macro levels health impacts are measured in terms of QALYs and DALYs in our analysis we are more concerned at assessing benefits in terms of reduction in illness that results in reduced medical costs and other gains such as money saved on treatment, medicine and increase in employment opportunity as work days lost on account of illness are reduced. But estimating them is not easy if base line data is not available.

Please note that these gains arise on account of reduction in use of harmful inputs in terms of quantity and use of lesser toxic inputs. The economic gains on account of this are captured in data on costs and benefits. Here we are computing only the money saved that otherwise would have been spent on cost of medicine, fees to doctor and related costs. The long-term health benefits could be more than this and money saved might not be the appropriate indicator for that. Having said that we want to indicate the measurement here pertains to illness and treatment arising out of handling harmful chemicals during cultivation and not for other causes or consequences. Hence caution needs to be exercised in assessing the health impacts. So data collection and/or modeling for health impacts has to be sensitive to this. What has to be measured is Gain in health benefits of farming families and farm labor and other involved groups in terms of health gain/health support, correction of health disorders, reduction of episodes of illness.

(2) For fortified foods, if that is the trait, the benefits in terms of nutrition, impacts on health and economic benefits have to be assessed. Enhancement of the non-LMO through trait can result in enhanced availability of carbohydrates, vitamins or more calories. The health benefits and economic benefits have to be assessed including reduction in/avoidance of disease/deficiency. The regulator will be interested in knowing how the conferred trait is translated into such gains in real world applications. Hence data in terms of components of food/output and the baseline data of the non-LMO crop will have to be compared.

11.5.3 Environmental Dimension

The environmental impacts are more difficult to quantify in terms of monetary units. Nevertheless there are methods to assess them. Risk assessment studies indicate the potential environmental risks and benefits and the focus here is to assess the environmental benefits at the farm level. Hence the environmental gain at the farm level has to be evaluated on the basis of data or from risk assessment modeling. Reduced toxicity in the environment, less harm to birds and beneficial organisms, reduction in toxicity of the soil, reduction in damage to other flora on account of reduction in use of lesser quantity of chemicals and reduction in or avoidance of hazards from non-LMO cultivation are some of the relevant measurements. Modeling studies can predict these or indicate the potential positive changes and to validate this, the regulator may ask for data or data from the farms. The regulator knows that environmental benefits may not be the same or uniform in all farming environments and hence site or field specific data may be required. Here the base line is that of non-LMO cultivation and only the benefits that can be attributed to change in cultivation have to be considered. Other factors such climate, changes in ecosystems, human intervention and changes in land use pattern can impact but regulator is more concerned with beneficial changes from LMO cultivation than with changes in environmental quality per se. Based on the model and data on farm or region the regulator will use the relevant indicator to measure environmental benefits. Further to differentiate the environmental benefits from other positive changes on account of non-LMO interventions comparative studies may be made.

Primarily, the benefits can be classified into three categories

(1) Effect on soil quality and water quantity and quality: This can be indirectly measured in terms of cost saved on account of avoidance of remediation or restoring the original quality. Environmental indicators will be used to assess quality of water and soil. Here the base line will be non-LMO cultivation. Bedsides quality, quantity of water is also a factor in assessment. The effects will be in terms of better environmental including soil quality and cost that was saved. For the regulatory purposes the environmental effects based on modeling or comparative studies, base line data and data on soil, water and environment will be required.
(2) The reduction in use of pesticides and harmful chemicals leads to lesser residues and decline in pesticide use results in less harmful effects on environment, animals and humans. Tested data for residues and reduction in pesticide use can be provided as data. For this soil samples will have to be tested and benefits of reduction in use of pesticides can be assessed in terms of traces of chemicals in the bodies of humans and animals. Environmental models can predict these and the data can be compared with this, controlling for other variables.
(3) Impact on agro-ecology: This is measured in terms of impacts on distribution of species/population in a specific farming system. In this the base line will tell the position prior to LMO cultivation and post-cultivation distribution can be measured. Here flora and fauna are taken into account. The regulator may demand additional evidence or data relating to impact of specific species which may be endangered or aesthetically significant or have cultural/spiritual significance.

The environmental impact will be a combination of the above three. Given the multiple impacts of LMO cultivation in farming ecosystems the regulator will take a holistic perspective than going by simply positive or negative aspects or impacts. The risk assessment, environmental modeling exercises and environmental quality indicators will be used. If the regulator perceives that some negative aspects are significant despite over all positive impact, special measures or efforts may be suggested to overcome them. Regulators will be interested in both short term and long-term environmental assessment and hence may call for efforts in long-term assessment to be taken up.

11.5.4 Social Dimension

The social benefits to be assessed are primarily distributional effects on different groups. This is in addition to economic gains/benefits which may not be uniform across all types of producers. Gender is an important dimension to be considered.

The list below gives an indication about the impacts to be assessed and how to assess them. The regulator may seek more impacts to be assessed.

(1) Assessing the rate of return by farm size: This assessment is similar to the ones mentioned earlier under economic impact assessment. Here the same methodologies can be used. The purpose is to know whether smaller farms are able to get adequate rate of return from the LMO or are the returns are skewed in favor of large farms and if so, on account of what factors. In other words regulator wants to assess whether the technology is neutral vis-a-vis the farm size.
(2) Assessing impact on labor (from perspective of labor): In this the wage and the availability of employment for labor are to be considered. The regulator may want to know whether the technology adversely affects demand for labor and if so at what stage of cultivation. Further the effect of technology in terms of economic loss on account of reduction in labor employed and workdays lost on account of adoption of technology are important. Technology may reduce the need for labor in some operations or in some operations owing to reduction in use of input such as chemicals/pesticides labor may not be needed as in the case of non-LMO crop. But more labor may be needed to pluck or to harvest on account of increase in yield. So the overall impact is important for understanding. The non-farm employment opportunities should also be factored in and whether the technology displaces labor to non-farm work should be assessed. The methodology could be survey and the data should capture, inter alia, employment pattern and income; labor usage time and income; changes in employment and costs/benefits for labor.
(3) Distribution of benefits by caste, both, as farmers and as workers can be assessed by survey. Here the regulator may link this with farm size, farm ownership and other factors to assess how benefits are impacted by caste and whether all castes benefit uniformly from technology as farmers and as laborers. As some farmers may also work as farm hands in some seasons when they are not cultivating, regulator may seek further data to understand this and whether this is due to factors related to technology or factors external to that.
(4) Assessing impact on women (women farm labor and women as farmers perspective): This is similar to item 2 as above. The regulator will assess impact of technology on women as workers and as farmers to find out whether the technology is gender neutral. The methodology could be survey and the data should capture, inter alia, employment pattern and income; labor usage time and income; changes in employment and costs/benefits for labor.

11.5.5 Cultural Dimension

Among the dimensions of SE assessment, impacts on culture are the most difficult to measure as it is difficult to quantify this. Further the linkage between technology, values/norms and society is straight forward. Never the less the regulator has to ensure that the technology is not culturally offensive or harmful and it does not result in outcomes that negatively impact societal norms and values. The following are suggested as criteria to assess cultural impacts.

(1) Equity and Inclusivity: This covers degree of equitable access to technology and information and whether the technology promotes inclusive development or deepens socio-economic inequalities.
(2) Cultural Compatibility: Whether the technology is aligned with cultural and aesthetic values regarding food.

11.5.6 Engagement with Stakeholders

As part of SEA engaging with stakeholders is essential. Only then the perception of the stakeholders can be assessed and that can be made part of SECs. Through questionnaries and other methods, the institutions in this project assessed the views and perceptions of stakeholders while a theoretical perspective on risk, perception and democratization of science and technology has been provided in Chap. 4.

11.6 Taking the Frameworks and Guidelines Forward

The above Guideline Framework was developed in the context of the research project described in Preface. They are based on inter alia, findings from field work and literature survey. It is to be tested and based on the experience it can be suitably modified and revised. It can be compared with the suggestions of AHTEG as described in CBD/CP/MOP/9/10 containing "Guidance on the assessment of socio-economic considerations in the context of Article 26 of the Cartagena Protocol on Biosafety". Similarly it can be compared with other frameworks and guidelines mentioned in the literature. While such a comparative analysis is important, we are of the view that the it can be made more robust and agile by revisiting and making it relevant for applications like gene edited crops and gene drives. However, such an exercise is beyond the scope of this volume.

Finally developing guidelines and frameworks cannot be a task similar to ploughing alone in a field. It has to be an endeavor with contributions from stakeholders, academics and think tanks so that the task of implementing Article 26.1 can be taken forward and better guidelines and frameworks are developed based on theory and praxis. Our humble submission is that the Guideline Framework described in this volume can be considered as a contribution to that task.

11.7 Conclusion

Most of the methodologies for SEA focus on economic indicators while some have integrated socio-economic factors. In this chapter, we have highlighted the relevant key objectives, socio-economic indicators, principles and methodologies for undertaking a comprehensive socio-economic assessment of LMOs. A guideline framework has also been proposed in this chapter illustrating all the key dimensions and factors in SE assessment that have to be taken into account including economic, social, environmental, health and cultural. Obviously this is the first step in a long journey.

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Chapter 12
A Way Forward: New Trends in Technology and Relevance of Socio-economic Assessment

Krishna Ravi Srinivas

Abstract When CPB was negotiated, concern was on the impacts of GMOs. But now there are new technological developments such as Gene Drives, GM Mosquitoes and Gene Edited Crops. These developments are likely to have far reaching consequences than GMO as they have the potential for far more wider applications and raise ethical, legal and regulatory challenges. At the same time, whether the regulatory regimes developed for GMOs and genetic engineering would be adequate to govern them is a big question. CBD is trying to address challenges such as synthetic biology and assess their impacts for biodiversity. Will Article 26.1 be relevant for governing these technologies and what role it can play in governing them is a question. But given their impacts on environment, particularly on biodiversity, it is likely that CPB may emerge as the most important international instrument in global governance of some of these technologies. In case of Gene Edited Crops, the regulatory regime is emerging and likely to take final shape in the next few years. In this chapter it is contended that Socio-Economic Assessment is important in any governance regime for these technologies and CPB through Article 26.1 can enable development of such assessments. Further it is also stated that while lessons from implementation of Article 26.1 are important, to face these new challenges the current guideline frameworks and methodologies will have to be revised.

Keywords Gene edited crops · GM mosquitoes · Gene drives · Synthetic biology · Governance

12.1 Introduction

In the other chapters in this volume the discussion has been on LMO/GMO as the CPB deals with LMO and Article 26.1 has been interpreted and implemented in the context of GMOs, GM crops and products derived from GM crops. When CPB was negotiated and agreed to in early 2000s GMO and LMO were the predominant technologies

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that were of much concern and focus was global trade in LMO and GMO. Over the years as LMO/GMO have been well adopted and the respective technologies to produce and process them have diffused globally, although not uniformly. Thus CPB has been found more or less adequate in dealing with them. Simultaneously the regulation regimes for biotechnology have undergone major change in the last two decades. But new applications like GM mosquitoes, Gene Drives and Gene Edited Crops (GEC) raise new issues, ranging from classification to principles of governance. Even if this is accepted the question as to whether SEC and SEA are relevant for them arises, partially because SEC has figured hardly in the debates on governing these technologies. Another reason is that while SEC and SEA are discussed in the context of environmental law, the discourse on governance of new technologies is not confined to environmental law.

Technology Assessment (TA) is a standard practice undertaken to get a better understanding of overall effects of a technology and to assess how they can be handled. Addressing Ethical, Legal and Social Implications (ELSI) is another method that can be used to supplement TA or be undertaken independent of this. Often examination of ELSI aspects covers perspectives from bioethics also Socio-economic considerations, and, socio-economic assessment differs from TA and ELSI. A significant difference is that in socio-economic assessment in the context of CPB greater importance is given to assessing the impacts on biodiversity and traditional communities. The objective of including socio-economic considerations or undertaking socio-economic assessment under CPB is to aid decision making. In case of LMO/GMO, these are done often as an addition to risk assessment process. While risk assessment is a scientific process, socio-economic assessment goes beyond assessing the economic benefits and costs of a LMO. Risk assessment is undertaken at different stages, while socio-economic assessment is undertaken either during the decision making or in regulatory process and/or continued after approval in different stages of life cycle of LMO/GMO.

Seen in this light it may be necessary to adopt SEA or SEC for the new technologies and applications with modifications/revisions from the current methodologies, frameworks and regulations. For example, stakeholder engagement will have to be given more importance than now. Similarly risk assessment regimes will have to take into account more uncertainties in risk assessment. However, there are some fundamental issues that need to be addressed on governance of these technologies. For example, with respect to gene-edited crops whether they should be considered as GMOs or not for regulatory purposes is a major issue (Srinivas 2018) (See also Ishii and Araki (2017), Johnson (2015)).

According to Hefferon and Herring (2017)

> We can confidently predict that there will be significant controversy over how to classify and regulate or normalise genome edited crops. Whatever the outcome in particular places or times, it is unlikely to be consistent, generalisable or enforceable. There is already great incoherence and inconsistency in the concept of "GMO," making it "practically impossible to define" in law or biology (Johnson 2015). The dominant criterion has been cross-species transfers of genetic materials – transgenesis.

While Gene Edited crops may be technically sweet solutions, it is interesting to note that a survey on views of experts found that socio-economic considerations will play a key role in consumer and regulatory perception of this technology (Lassoued et al. 2019).

12.2 Challenges in Risk Assessment, Governance and Socio-economic Assessment

New developments in technology can result a revision in terminology regarding LMO and this has implications for CPB, particularly Article 26.1. 26.2. For example, gene editing is more advanced and more widely applicable than genetic engineering technologies used in developing LMOs/GMOs. As products can be developed without inserting foreign gene and the very idea of 'genetic modification' may have to be revisited for risk assessment and regulatory purposes. Although no foreign gene might not have been inserted the genetic components of a product might have been changed and these may be nearly identical to the ones which have not undergone gene editing. So principles like substantial equivalence may have to be revised and recalibrated in light of technological development. We may need more clarity on defining LMOs and differentiating LMOs and GMOs from products developed through gene editing and other novel technologies. As Lassoued et al. (2019) point out applications of genome editing can result in different outcomes and not all of them can be classified as GMO. According to them "*Some modifications (SDN 1 and SDN 2) can be generated by chemical mutagenesis, radiation or natural mutations, with the resulting organisms similar to those obtained by traditional breeding or classical mutagenesis (e.g. glyphosateresistant CRISPR rice for weed control). Other repair mechanisms involve delivering foreign DNA (SDN 3), with the outcome that the resulting products would be viewed as transgenic for regulatory risk assessments*." (Lassoued et al. 2019, p. 249). While this has implications for CPB, how regulatory regimes deal with this is equally important. For example, if a country decides that gene edited crops need not be treated as GMOs but as equivalents of crops developed through traditional plant breeding technologies, then the regulatory framework for GMOs becomes non-applicable to them and the framework that regulates crops varieties developed through traditional plant breeding is applicable. In such a case, the rules of CPB are not applicable for them. Which practically means that Article 26.1 is not applicable as far as that country in concerned. Suppose if country A deregulates gene edited crops as described above and if country B which treats them as LMO want to import them from country A, can still use SEA and opt for using SEC in decision making under Article 26.1. Hence Article 26.1 will be relevant in that country.

Right now, the trade implications of gene edited crops vis-a-vis applicability of CPB is not clear as the regulatory regime for such crops is not fully developed. According to Duensing et al. (2018)

> Rules that determine whether or not an organism falls under a special GMO regulatory regime differ from one country to another. Quite often, their parameters for regulatory inclusion are based on product characteristics and/or the process used to obtain them. A recent review of the global GMO regulatory landscape which aims at anticipating the future scenario for genome-edited crops shows that the debate on "product-based" vs. "process-based" regulation is not the key influence when it comes to technology adoption (Ishii and Araki 2017). The article also reports that many national regulations depart from the LMO definition of the Cartagena Protocol which is worrying since the Protocol should act as a harmonising factor. But while these diverging definitions have so far not created major issues for the classification of a plant variety as GMO (or comparable categories) or as a conventional crop, genome editing and other NBTs represent a broader spectrum of technical possibilities. The combination of this variety of technical possibilities with the wide array of subtle differences in national regulatory touchstones, may asymmetries that can affect trade

In case of GM mosquitoes and Gene Drives, similar concerns may be applicable; although they may not be traded as much LMO/GMO or GM crops are. Still if countries classify GM mosquitoes as LMO, then CPB would be the most appropriate instrument for trading in them, in the context of risk assessment, prior informed consent and advance information providing. So it can be presumed that CPB will remain as the most appropriate international protocol to handle their trade, in addition to SPS Agreement of WTO.

Gene Drives are not covered explicitly by any of the environmental treaties in vogue. But among the conventions, treaties and protocols, CBD and CPB are the most relevant, given the impacts of Gene Drives on ecosystems, and, on biodiversity. The transfer, handling and use of Gene Drives can be covered under Nagoya-Kula Lumpur Supplementary Protocol on Liability and Redress. While discussions under CBD are on way regarding Gene Drives, the next COP-MOP to be held in 2020, is expected to deal with issues relating to Gene Drives. After examining the developments related to Gene Drives and international environmental law, Rabitz cautions that their regulation under CBD and CPB may not be adequate. He points out that specific measures on Gene Drives can be included as a broader package deal so that they can be regulated under CBD (Rabitz 2019). In such a scenario, invoking Article 26.1 will make sense, as a comprehensive SEA will be necessary to aid any decision making. Since SEA is a broad assessment, it can provide valuable insights on impacts and on the long term consequences of adopting Gene Drives. In such a case, SEA will have to conduct ecological risk assessment as suggested by NAS rather than mere environmental impact assessments (NAS 2016, p. 139).

Transboundary movement of Gene Drives can create an externality problem as they are designed to spread. There are two possibilities to govern them, one of them is based on WTO while the other is based on CBD. Under WTO, the relevant ones are Codex Alimentarius that covers, Food safety standards and GMOs, International Plant Protection Convention and Phytosanitary standards with biocontrol standards as precedents and adopting WHO standards for GM mosquitoes. In case of CBD, the relevant rules/instruments are Cartagena Protocol for dealing with intentional and unintentional introduction of LMOs, use of Biosafety Clearinghouse as logical repository for risk assessment and adopting Supplementary Nagoya-Kuala-Lumpur

Protocol for s liability and redress for transboundary introductions of LMOs (Brown 2016).

While governing under WTO may be feasible, governance under CBD makes more sense, given the impacts of Gene Drives. Although the current norms of CBD and CPB may not be adequate to cover them, still they are better suited for governing Gene Drives. In such a case, it is better to start a round of negotiations to formulate new provisions and modify the current ones than to leave it entirely under WTO rules. If this were to happen then Article 26.1 will also be applicable and thereby SEA and SEC will become part of governance regimes.

Adoption of GM mosquitoes raises many issues relating to ethics, patenting, unintended consequences and hence better community engagement is essential (Meghani and BoeÈte 2018) Although the authors have not discussed the relevance of Article 26.1, to address some of their concerns, Article 26.1 will be an effective approach.

The above brief discussion highlights some of the challenges in governing these new technologies and the relevance of Article 26.1. But I am not suggesting that this is a panacea for all issues related to governance of these technologies and to assess their implications.

12.3 Way Forward

In light of the above discussion and points discussed in different chapters, the following are suggested as way forward

(1) With the work of AHTEG reaching a crucial phase, debates in CPB on SE considerations and framework for SE assessment have reached a critical phase. There are indications that a shared understanding is emerging. But some aspects in SEA such as conducting SE assessment in different phases in life cycle of LMO, have not received the attention they deserve. This should be addressed so that the SEA process and the inputs and outputs are made more relevant and robust.

(2) Given the wider implications of new and emerging technologies such as gene editing and novel plant breeding technologies, substantial research on their implications for biodiversity and ecosystems and research on long term impacts is necessary. Such research should be undertaken in such a way that SEA process and SE considerations and the research complement each other.

(3) It is now widely recognised public engagement has a vital role to play in developing regulatory regimes and in governance of these emerging technologies. As tools and methods for such engagement are getting more sophisticated the theory and practice on SEA and SEC should reflect on this and examine how public engagement can be given a better role than what is currently assigned to it, in SEA process and in regulations.

(4) As these technologies raise novel issues in terms of ethics, governance, certainty and uncertainty in risk assessment and unanticipated consequences, it is essential

that those who do research on and those who implement SEA or processes related to SEC pay attention to them and identify how these can impact SEA and using SEC for decision making.

(5) Finally, the methodologies and guideline framework discussed in this volume will have to be revisited in light of the above discussion. We will certainly work on that, even as we try to understand the debate and discussions on governance of the emerging technologies.

12.4 Conclusion

In this chapter the relevance of SEA and SEC for governance of emerging technologies such as gene edited crops has been discussed and some suggestions have been made. As in the next COP-MOP to be held in 2020 issues related to Gene Drives and Synthetic Biology are to be discussed, it is essential that development of guidelines and frameworks should also be part of the broader debate so that the relevance of CPB in governance is addressed.

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Appendix
Model Questionnaire

Prepared for the Project

"Developing Guidelines and Methodologies for Socio-economic Assessment of LMOs"

Reference Period: Schedule Number:

Reference Crop	Trait

PART I

A. General Information

Village		Name of the Investigator	
Tehsil/Taluk		Date of Interview	
District/Block		State	

B. Details of the Respondent:

Name of the respondent:	Contact. No:	
Respondent's age:	Gender: (Male =1; Female=2)	
Number of years of education:		
Caste:________SC=1; ST=2; OBC=3; Others=4;		
Sources of Income (Rs / Annum):	Agriculture and allied activities:	
	Others:	
Number of years of farming experience		
Number of years of experience of LMO crop cultivation:		
Number of years of experience of conventional crop cultivation:		

S. Chaturvedi and K. R. Srinivas (eds.), *Socio-Economic Impact Assessment of Genetically Modified Crops*,
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C. Details of Household Members and labour utilisation (Including respondent)

Category	Total No of persons	Working in own farm		Working in other farms	
		No. of hrs/day	No. of months/ annum	No. of hrs/ day	No. of months/annum
Male (>16 years)					
Female (>16 Years)					
Children (<16 years)					

D. Land related Information (area in acres)

Type of Land	Irrigated	Rainfed	Source of Irrigation*	Rental Value (Rs/acre)	Soil type
Total owned land					
Leased-in					
Leased -out					
Uncultivated land					
Total					

*Open well =1, Tube well=2, Tank =3, Canal = 4, Others=5

E. Farm Assets

Assets	Qty./No.	Year of purchase/ construction	Purchase/ construction value (Rs.)	Annual repair and maintenance cost (Rs.)	Annual Rental Value (Rs.)
Well/tube-well					
Pump sets					
Drip system/irrigation systems					
Tractor and tractor drawn implements					
Farm sheds					
Drying Yards					
Plough					
Sprayer					
Small tools (sickle, hoe, machete, etc.)					
Cattle shed					
Cattle					
Buffalo					
Goat/ Sheep					
Others					

F. Details of cropping pattern

Season/Crop	Area (acre)		Source of irrigation Code*	Total Production (qtl)		Quantity Sold (qtl)		Average Price (Rs/qtl)		Cost of cultivation in Rs.
	Irrigated	Rainfed		Main	Byproduct	Main	Byproduct	Main	Byproduct	
Kharif										
Rabi										
Summer										
Annuals / Perennials										

Source Code (major source)*: Open well =1; Tube well =2; Canal =3; Tank =4; Others =5.

G. Details of area and production for the reference crop (_______________) during the last 2 years

Year	Area (acres)			Production (qtls)			Price			Remarks
	Kharif	*Rabi*	Summer	*Kharif*	*Rabi*	Summer	*Kharif*	*Rabi*	Summer	
2012-13										
2013-14										
2014-15										

H. Credit Details

Name of the agency	Amount (Rs.)	Purpose of loan	Rate of interest per annum (%)	Month of borrowing	Time of repayment	Amount Paid (Rs.)	Outstanding loan amount (Rs.)
Commercial Banks							
Cooperatives							
Private Banks							
Traders/money Lenders/ friends/relatives							

I. Major constraints faced in the cultivation of reference crop____________________

Sl. No.	Particulars	Yes/ No	Severiety of the problem (Low =1;Medium=2; High=3)												
1	Problematic soils (salinity/alkalinity)														
2	Quality of seed														
3	Avaliability of labour														
4	Incidence of pests and diseases														
5	Weeds														
6	Water stress														
7	Cost of inputs														
8	Others (Specify)														
9	Others (Specify)														

Area (acres): Variety: LMOs Season:*Kharif* **J. Cost of Cultivation for reference crop (For whole area)**	Crop duration: Days	Wage rate (Rs./day):	Male: Female:

Sl. No.	Operations	Bullock power (Rs.)		Machine power (Rs.)		Human labour				Inputs		Remarks
						Total no. of family labour		Total no. hired labour		qty.(kg).	Value (Rs.)	
		Hired	Owned	Hired	Owned	M	F	M	F			
a	Land Preparation											
b	Seed/seedling											
c	Sowing											
d	Irrigation (acre-inches)											
e	Weeding											
f	Intercropping											
g	FYM ,Organic/Bio-fertilizers											
h	Urea (N)											
i	Phosphorus (P)											
j	Potash (K)											
k	Complex ferti:_________											
l	Other ferti_________											
m	Micro Nutrients											
n	Weedicide											
o	Insecticide											
p	Pesticide											
q	Harvesting											
r	Threshing											
s	Bagging, transportation & marketing cost											
t	Others											

K. Cost of Cultivation for reference crop (For whole area)

Area (acres): Variety: LMOs Season:Summer/*Rabi*	Crop duration: Days	Wage rate (Rs./day):	Male: Female:									
RemarksInputsHuman labourMachine power (Rs.)Bullock power (Rs.) OperationsSl. No.												
Value (Rs.)qty.(kg.)Total no. hired labour Total no. of family labour												

OwnedHiredOwnedHired FMFM Land Preparationa Seed/seedling b Sowing c Irrigation (acre-inches)d Weedinge												
	Intercropping											
	FYM ,Organic/Bio-fertilizers											
	Urea (N)											
	Phosphorus (P)											
	Potash (K)											
	Complex ferti: ____________											
	Other ferti________											
	Micro Nutrients											
	Weedicide											
	Insecticide											
	Pesticide											
	Harvesting											
	Threshing											
	Bagging, transportation & marketing cost											
	Others											

L. Cost of Cultivation for conventional crop (For whole area)

Area (acres): Variety:Conventional Season:*Kharif*	Crop duration: Days	Wage rate (Rs./day):	Male: Female:									
Remarks Inputs Human labour Machine power (Rs.)Bullock power (Rs.) OperationsSl. No.												
Value (Rs.)qty.(kg.)Total no. hired labour Total no. of family labour												
OwnedHiredOwnedHired FMFM Land Preparationa Seed/seedling b Sowing c Irrigation (acre-inches)d Weedinge												
	Intercropping											
	FYM ,Organic/Bio-fertilizers											
	Urea (N)											
	Phosphorus (P)											
	Potash (K)											
	Complex ferti:________											
	Other ferti________											
	Micro Nutrients											
	Weedicide											
	Insecticide											
	Pesticide											
	Harvesting											
	Threshing											
	Bagging, transportation & marketing cost											
	Others											

M. Cost of Cultivation for conventional crop (For whole area)

Area (acres): Variety: conventional Season:Summer/ *Rabi*	Crop duration: Days	Wage rate (Rs./ day):	Male: Female:									
Remarks Inputs Human labour Machine power (Rs.)Bullock power (Rs.)OperationsSl. No.												
Value (Rs.)qty.(kg.)Total no. hired labour Total no. of family labour												
OwnedHiredOwnedHired FMFM Land Preparationa Seed/seedling b Sowing c Irrigation (acre-inches)d Weedinge												
	Intercropping											
	FYM ,Organic/Bio-fertilizers											
	Urea (N)											
	Phosphorus (P)											
	Potash (K)											
	Complex ferti:________											
	Other ferti________											
	Micro Nutrients											
	Weedicide											
	Insecticide											
	Pesticide											
	Harvesting											
	Threshing											
	Bagging, transportation & marketing cost											
	Others											

PART
II

TRAIT RELATED INFORMATION

A. Details of seed for the reference crop ______________

S.No	Particulars	Variety 1 : ……	Variety 2: ……	Variety 3: ……	Variety 4: ……
1	Own=1;Purchased=2				
2	Qty. of seed purchased (Kg.)				
3	Price (Rs./kg)				
4	Sources of purchase				
5	How many years have you been buying seeds (of any kind) from this source?				
6	What is the location of the source of the seed: within the village=1;taluka/town=2;others=3				
7	Distance from the source (Km)				
8	Germination quality Low=1;High=2				
9	Who decides the variety to be sown: self=1,head of the HH=2, joint/collective =3; Government=4;University/KVK=5; Prívate company=6; other= 7(specify)				
10	Which year did you first plant this variety?				
11	Area planted in the first year.				
12	Mention previously cultivated variety and the year				
13	Reasons for cultivating this variety				
15	Did the seller persuade you to buy any variety other than you wanted? Yes=1; No=2				
16	Whether technical advise was provided by the seed seller? Yes=1; No=2				
17	Did you purchase seed on credit =1 or cash=2 ?				
18	What other inputs do you buy at this shop/source?				

B.WEED MANAGEMENT

B.1. Incidence of weed for the reference crop

Name of the weed	Frequency of Incidence (every season=1;once in a year=2)	Severity of incidence (low=1;médium=2;high=3)	Stage of incidence#	Estimated yield loss (%)	Remarks
Kharif					
Rabi					
Summer					

seedling/sowing=1; vegetative stage=2;flowering=3;grain formation=4

B.2. CONTROL OF WEEDS

B.2.1. Cultural Method

Summer Ploughing							
Wage Rate (Rs.)Total LabourRate per hour (Rs.)HoursOwned /hiredMachinery/Animal Power FemaleMale FemaleMale Inter Cultural Operations (manual/machine weeding) *Kharif*							
Rabi							
Summer							

B.2.2. Chemical method

Herbicide#	Control which weeds	No. of Spray	Qty. (ltr/kg.)	Value (Rs.)	Labour charge (Rs.)	Sprayer Hiring (Rs.)	Nature of herbicide*
Kharif							
Rabi							
Summer							

#Write the chemical name and trade name; * Pre emergence/Post emergence

B.2.3. Biological method

Name of the biological agent	No. of release	Time of release	Qty.	Value (Rs.)	Labour charge (Rs.)	Remarks
Kharif						
Rabi						
Summer						

C. INSECT PESTS AND DISEASE MANAGEMENT

C.1. Incidence of Pests and Diseases for the reference crop

Name of the pest and diseases	Frequency of Incidence (every season=1;once in a year=2)	Severity of incidence (low=1;médium=2;high=3)	Stage of incidence #	Estimated yield loss (%)	Resistant varieties	Remarks
Pest						
Kharif						
Rabi						
Summer						
Disease						
Kharif						
Rabi						
Summer						

seedling=1; vegetative stage=2;flowering=3;grain formation=4

C.2 PEST AND DISEASE CONTROL

C.2.1. Cultural Method

A. Did you adopt summer ploughing for control of pest and diseases? Yes/ No, If yes fill the table B.2.1.A

B. Mechanical (pick and destroy, cut and burn, etc.)					
Machinery/Animal Power	Owned /hired	Hours	Rate per hour (Rs.)	Total Labour (days)	Wage Rate (Rs.)
	Male	Female	Male	Female	
Kharif					
Rabi					
Summer					

C.2.2. Chemical method

Insecticide/ fungicide /nematicide #	Control which insect pests / diseases	No. of Spray	Qty. (ltr./kg.)	Value (Rs.)	Labour charge (Rs.)	Sprayer Hiring (Rs.)	Nature of chemical *
Kharif							
Rabi							
Summer							

#Write the chemical name and trade name; * Contact=1, systemic =2 and others (specify)=3

C.2.3. Biological method

Name of the biological agent	Method of application#	No. of release	Time of release	Qty	Value (Rs.)	Labour charge (Rs.)	Remarks
Kharif							
Rabi							
Summer							

seed treatment=1; soil application=2; others(specify)=3

D. WATER MANAGEMENT

D.1. Water Use

Particulars Groundwater	Crop 1:…………..	Crop 2:……………..	Remarks										
Area (acres)	Conventional	LMOs	Conventional	LMOs									
Number of irrigation per week	K	R	S	K	R	S	K	R	S	K	R	S	
Number of hours per irrigation													
Discharge of wáter (inches)													
Water charges (Rs.)													
Surface wáter (canal/tank)													
Area (acres)													
Number of irrigation per week													
Water charges (Rs.)													

PART III

FARMERS AND CONSUMERS PERCEPTION ABOUT LMOs/GMOs

i. If a new variety with desired trait (drought tolerant/insect resistant) release______, would you be willing to pay for this seed: Yes/No
If yes. How much?

a. < 10% of what you paid last season
b. 10-25% of what you paid last season
c. 25-50% of what you paid last season
d. > 50% of what you paid last season

ii. What other crop traits you prefer ?____________

iii. Why did you choose your primary seed source?__________
(1 No other choice, 2. reasonable price, 3. Good quality, 4. nearness, 5. Trust the source, 6. Available on credit 7. Technical advice, 8.Others)

iv. Apart from your primary source of seed, which other sources of seed do you know of? ----------------

v. For the past how many years have you been experiencing the present problem (trait related) which is constraining the production or productivity?
----

vi. What price should be fixed for LMO crop output with desirable traits
(a) Same as that of existing crop (b) 1.25 times more (c) 1.5 times more (d) 2 times more

vii. Do you apply yourself Pesticides (insecticides, fungicides) or Herbicides? (Yes/ No):_____

viii. If you or the person applying the chemicals experiences any health problem during or after insecticide sprays, please give details.

Health Impairment	Frequency of illness (No. per year)	Working days, fully lost due to illness (per year)*	Working days, partially lost due to illness (per year)*	Average reduction in working hours per days	No. of times sought treatment for illness(per year)	Cost of medicine (Rs./year)	Fee paid to physician (Rs/visit)	Travel cost to meet Physician (Rs/visit)
1.Nausea								
2.Stomach Pain								
3.Diarrhoea								
4.Severe cold								
5.Asthma								
6.Other respiratory problems								

7.Coughing								
8.Eye irritation								
9.Blurred vision								
10.General Weakness								
11.Fever								
12.Sleeplessness								
13.Wounds								
14.Skin irritation								
15.Others (Specify)								

*Working days lost by the household, which also includes time spent by the family members in treating the illness.

ix. Did you receive training on how to use pesticides or herbicides? (Yes/ No)
If yes, from whom? Specify:________

ix. Do you or your farm labourers use gloves, cover mouth and nose, and protective clothing when applying? (Yes/ No)

x. Do you or your farm labourers wear boots when applying chemicals? (Yes/ No)

xi. Do you or your farm labourers wear spectacles? (Yes/ No)

xii. Do you or your farm labourers follow wind direction while spraying? (Yes/No)

xiii. How do you dispose chemicals/containers?:________

xiv. Do you or your farm labourers eat and drink while applying chemicals? (Yes/ No)

xv. Do you or your farm labourers smoke while applying chemicals? (Yes/ No)

xvi. Do you or your farm labourers wash hands/bathing after applying chemicals? (Yes/ No)

xvii. Do you use more=1, less=2, recommended doses=3 of herbicides and pesticides? Indicate ….

xviii. **Access to extension services**

a. Did you receive any advice/training in the past two seasons from any service provider (agricultural extension services) for crop production? (Yes/No) ______

b. If Yes, please provide the details below

Service Provider	Frequency of seeking information#	Total number of visits in past one year
Government agency		
Universities/KVKs		
Input dealers		
Farmer group member		
NGO		
Other fellow farmers		
Project/program/volunteer providers		
Other (specify)		

Regularly=1,Occasionally=2,Rarely=3,Never=4

I. Do you seek information about market prices before you plant? (Yes/No)______

II. Do you seek information about market preferences before you plant? (Yes/No)____

III. **Knowledge about LMOs (Farmers' Perspective)**

1	Do you know about genetically modified crops?	Yes / No
2	If yes , what GM crop you heard about?	
3	Have you ever cultivated Bt cotton (GMO)?	Yes/ no
4	If yes, did GM cotton give higher yield than other hybrids? What is the increase in yield per acre (%) ?	Yes/ no
5	If yes, did GM cultivation led to increase in your income or profit? By what percentage?	Yes/No
6	Do you find quality differences of reference crop(____________) is better than conventional variety If yes, provide details : (whole or broken grain/weight/color of grain or seed/ nutrition quality)	
7	Do you percieve any environmental risks in growing GM crops? List out:	Yes/No

Knowledge about LMOs (Consumers' Perspective)

1	Do you know about genetically modified foods/crops?	Yes / No
2	If yes , what GM food/crops you heard about?	
3	Have you ever eaten any GM food?	Yes/ no
4	If yes, what GM food have you eaten?	
5	If no, would you prefer eating any GM food?	Yes/No
6	If yes, why would you prefer eating any GM food?	
7	If no, why would you not prefer eating any GM food?	
7	Would you prefer any eating any GM food if it is cheaper?	Yes/No
8	Would you prefer any eating any GM food if it is healthier?	Yes/No
9	Would you want GM food to be labeled?	Yes/No
10	Do you think GM food is harmful to health?	Yes/No
11	Do you find the media reports trustworthy?	Yes/No

Risk Perception about GMOs:

How do you perceive about GM crops like Bt cotton being promoted in India? Given below are statements related to GM crops. Kindly mark the level of your agreement or disagreement with respect to each statement by putting a tick mark in the appropriate cell.

S.No.	Statements	Strongly Agree	Agree	Somewhat Agree	Disagree	Strongly Disagree
1	GM crops like Bt cotton will be beneficial for farmers					
2	Adoption of GM seeds will reduce the cost of cultivation.					
3	Cultivation of GM crops will ensure food security for the rapidly growing population (for aerobic rice only).					
4	Cultivation of GM cotton will be risky as pollen flow from GM plants will contaminate other neighbouring crops.					
5	Since GM crops carry genes from different species they will cause harm to the human and cattle.					
6	Entry of GM food in food chain will cause health risk					
7	Cultivation of GM crops will harm agro-biodiversity.					
8	The production and trade of GM seeds will increase the monopoly of big companies in the seed market.					
9	Rigorous scientific testing is done prior to release of GM crops					
10	Genetic engineering scientists tend to conceal data about harmful effects of GM crops					
11	Only the large farmers will be benefitted by genetic engineering technology.					
12	Promotion of GM technology will cripple indigenous knowledge system.					
13	Genetically modified foods should be labelled for the benefit of consumers.					
14	Information on biotechnology provided by mass media sources is trustworthy					
15	Prevalence of secondary pests will increase					
16	GM technology is required for few crops					
17	Promotion of GM crops will pose a serious threat to GI marked high value crops (e.g. Basmati rice)					
18	Deployment of GM crops will raise the cost of cultivation					

Index

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https://doi.org/10.1007/978-981-32-9511-7