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

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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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