Making Research Collaborations: Learning from Interdisciplinary Engagements

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"In science, novelty emerges only with difficulty, manifested by resistance, against a background provided by expectations".

—Thomas S.Kuhn (The Structure of Scientific Revolutions)

We use this quote by Kuhn, (1962) as the backdrop for the relevance and need of interdisciplinary research in making science work for society through a two-way flow of knowledge between science and society. Real world problems are complex and attempts of any one discipline to address these problems result in solutions that are either insufficient or not adaptable to real world situations (IOM, 2000a). Research seeking real world solutions for real world problems need to be based on an interdisciplinary perspective, with multiple disciplines complementing and contributing in completing the jig saw puzzle (Steyaert and Jiggins 2007; Ravetz 2006; Verran 2002, Jeffrey, 2003). Many ground breaking advances in science and technology, like the discovery of the DNA structure and development of MRI and GPS techniques, have been achieved from combining results from fields once thought to be unrelated. A survey conducted in 1980, by Sigma Xi- The Scientific Research Committee among its members about the need for interdisciplinary research funding for scientific problems that do not fit within arbitrary disciplinary structures, show 75 percent of the respondents reporting they either 'agreed' or 'agreed emphatically' (IOM, 2000b). But despite this agreement, traditionally, there has been a persistent barrier to interdisciplinary research from the scientific community (Dusseldorp and Wigboldus, 1994), even when all of the complementing disciplines fall in the realm of technical sciences. These barriers to interdisciplinary research collaborations ranges from being attitudinal barriers at the individual level to shared fear across the scientific community of research being graded second rate when it is not dealt with from within one disciplinary boundary. This is expressed by Paul Smolensky (IOM, 2000b) when he says that, '*disciplines have been able to investigate a given subject in depth. But when research bridges disciplines and this same depth cannot be attained, the quality of the research is perceived as poor'*[i]. While this has been the case of interdisciplinary research between disciplines within broad disciplinary boundaries like technical sciences and social sciences, research collaborations between them has been a still greater rarity. According to Bruce *et al*., (2004) who studied interdisciplinary projects with the aim of bringing about policy recommendations for the support and management of interdisciplinary research, there have been very few studies where technical sciences and social sciences collaborate.

But the late 2000's show a gradual shift in the scenario with the thrust of international funding driven from being singular discipline oriented to collaborative action research projects, across countries and across disciplines. Projects developed to cater to this shift in donor agencies thrust, without interdisciplinary perspective being incorporated or internalised right from the project inception phase, run the risk of resulting in a 'cosmetic

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interdisciplinary' (Sperber, 2006), with links between different disciplines remaining superficial. While Bammer (2013) reported that thinking on interdisciplinary perspectives are increasingly part of research approach due to four powerful drivers; "the inherent complexity of nature and society, the desire to explore problems and questions that are not confined to a single discipline, the need to solve societal problems, and the power of new technologies". When researchers from different disciplines collaborate differences between disciplines need to be negotiated. Parity, reciprocity and common language among the different partners are essential elements to make such collaborations a success (Mergendoller, 1980). Studies suggests that interdisciplinary approaches are helpful in assessing the ground level issues and priorities of men and women farmers, seek an integrated solutions by working together on the development of technologies in collaboration with user groups (Nuijten, 2010). Bammer (2013) suggested a need for standardized methodology for conducting interdisciplinary research while Nuijten (2010) argued that in interdisciplinary research there is no need to have defined research methods, it is open and thus it encourages innovation and creativity in scientific research and build bridges between knowledge systems.

This paper attempts to outline salient features of collaborations between technical science and social science in two multi-country, multi-partner interdisciplinary research projects in which the authors were involved. In both the projects broad inter-disciplinarity[ii] form is adopted in which large research team with different disciplinary backgrounds, organizations and culture. Collaborating disciplines in one of the project (SCF Project)[iii] was from 1) Climate Science2) Decision Science[iv] and 3) Social science (consisting of Agricultural Economics and Gender). Collaborating disciplines in the second project (Biotechnology Package Project) come from 1) technical science consisting of a) Microbiologists, b) Agronomists, c) Soil scientists, d) Plant physiologists, and 2) social science (consisting of Gender, Extension and Agricultural economics). The social scientists involved in the project were instrumental in bringing in a gender perspective to the project processes and outcomes. Documenting and sharing the experience of the process and outcomes of these collaborative efforts is expected to give us insights into the effectiveness in terms of degree of disciplinary engagement achieved through such collaborations. Effectiveness of the collaboration is in turn a reflection on the collaborations' success in reaching science to society. While the authors acknowledge that experience from these projects can only be taken as tentative conclusions, learning from this experience can serve as checklists/guidelines for appropriate planning and designing of similar interdisciplinary action research endeavours. Before delving into the details of the interdisciplinary engagement, an attempt is made to describe the nature of interdisciplinary engagement of the two projects described in the paper.

Nature of Interdisciplinary Research Engagements:

Often the terms interdisciplinary and multidisciplinary are used interchangeably. Swanson (1979) defines multidisciplinary research as research in which researchers work within disciplinary boundaries and contribute to addressing a common research problem, with limited cross-disciplinary coordination. In interdisciplinary research, different disciplines actively coordinate in planning, implementing and reporting (Klein, 1990 and 1996; Alpert, 1969; Luszki, 1958). Hence in interdisciplinary research unlike in multidisciplinary approach, disciplines cross academic boundaries and have the scope of informing each other's work and comparing results (Aram, 2004; Birnbaum, 1977).

Having said this, it should be acknowledged that there is wide variation in the amount and quality of coordination that occurs in interdisciplinary research collaborations. Based on the degree to which the knowledge from different disciplines is integrated and the research's intended audience/target categories of interdisciplinary research has been visualised (Aram 2004). Integration across disciplines is effected with the intention of either exploring new ways of producing knowledge or for exchanging new perspectives across disciplinary boundaries. Based on the intended audience/target, research can be classified as purely theoretical (as those directed at an academic audience), action/applied (as in research aimed to solve some societal problem) or a mix of theoretical and action/applied research aimed at theoretical advancement coupled with solutions for societal problem (Wesselink, 2009; Aram, 2004). Table 1 is an illustration of the categories of interdisciplinary research based on the interactions of attributes like purpose of integration and audience/target of research. Vertical axis in Table 1 shows the degree and purpose of integration and horizontal axis shows the intended audience/target. The boxes are indicative of the category of interdisciplinary research that results from the combination of the attributes. Box 1 is indicative of the category of interdisciplinary research in which the disciplinary knowledge is integrated across disciplines to produce new knowledge for the academic audience. Box 2 is indicative of interdisciplinary research where disciplinary knowledge is integrated to produce new knowledge for solving a societal problem.

Table1. Categorisation of Interdisciplinary Research based on Attributes

Purpose of Integration across disciplines	**Intended Audience/Target**	
	Academic/theoretical	**Society/action**
New Knowledge	Box 1- NKA	Box 2- NKS
New Perspective	Box 3- NPA	Box 4-NPS

NKA – New knowledge for academic; NKS- New knowledge for society
NPA – New perspective for academic; NPS – New perspectives for society
Source: After Aram (2004); Adapted from Wesselink (2009)

Box 3 category indicates collaborations in which only perspectives are exchanged across disciplines to produce new academic perspective or knowledge. Box 4 is indicative of research in which perspectives are shared across disciplines with the intention of producing knowledge for a societal context. The category of interdisciplinary research in box 3 and 4 where only perspectives are exchanged across disciplines is considered less radical compared to one's where disciplinary knowledge is integrated as in box 1 and 2 (Wesselink, 2009).

The interdisciplinary research dealt with in this paper falls in the category depicted in box 2. In both the projects, through integration of disciplinary knowledge, new products were being developed to enhance the adaptive capacity of rainfed farming communities of semi arid tropics and hill agro-ecosystems. In the project in which climate science collaborated with social science, the product being developed was Seasonal Climate Forecasts (SCF), which are given 3 to 6 months prior to the start of the season for farming in semi-arid region by the farmers. Access to climate forecasts is expected to induce risk-reducing strategic decision making by the end users[v]. In the second project in which the collaborating technical science team were from biotechnology and agronomy, the product being tested was a combination biofertilizers and cropping system resulting in the phenomena of bio-irrigation and bio-fertilisation (BIOFI). Bio-irrigation phenomenon is expected to occur only in specific intercropping systems having complementary root associations, and this was being tested out in finger millet-pigeon pea cropping system in the project.

The social science team served as an interface between the technical science research and the users of knowledge namely men and women farmers and other stakeholders across the agricultural value chain. Social science research was to make research outputs of the technical scientists more adaptable to the local context and also to disseminate the research outcomes to the target audience. In the initial phase of the project, the role of the social science team in both the project was to inform the technical science team of the socio-economic context of the target audience, the existing farming practices of the target community, the existing adaptive and coping strategies, and the aspirations articulated by the community with respect to expected research outcomes. This information was to be used to give direction to the research conducted by the technical scientists to make their research outputs useful and to be of an easily adoptable nature by the intended target community. Further, the social science team was also engaged in taking the research outputs to the community through a process of intensive engagement with them for adaptation/refinement to their context.

Interdisciplinary Partner Agencies:

The ‘SCF Project’ had collaborating institutions spread across, Australia, India, Sri Lanka and USA. The institutions are classified in accordance to their geographical location and the disciplinary expertise they bring into address the project objectives (Table 2). The case study discussed in this paper is largely based on the project experience from the project site in Tamil Nadu, India.

Table 2: Collaborating Institutions across Countries and Disciplines

Institution	Institution Focus	Disciplinary Contribution
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia	Research and Development	Climate Science(Climate Modelling) Social science (Social Network Analysis)
South Australian Research and Development Institute (SARDI), Australia	Research and Development (with a focus on science communication in the realm of farmers decision making under climate	Decision Analysis/Science Communication

	uncertainty)	
University of Tasmania (UTAS), Australia	Academics and Research	Climate Science(Climate modelling and crop modelling)
Tamil Nadu Agricultural University (TNAU), India	Academics and Research	Climate Science(Crop Modelling)
Acharya NG Ranga Agriculture University (ANGRAU) (now Pandit Jayashankar Agriculture University, India	Academics and Research	Climate Science(Crop Modelling)
M. S. Swaminathan Research Foundation (MSSRF), Chennai, India	Development and Research	Social science (Gender and Agriculture Economics)
Livelihood and Natural Resource Management Institute, Hyderabad, India	Development and Research	Social science (Economics)
University of Peradeniya, Sri Lanka	Academics and Research	Climate Science(Crop Modelling)
Practical Action, Sri Lanka	Development and Research	Social science (Sociology)
International Research Institute for Climate and Society (IRI), USA	Research	Climate Science(Climate Modelling)

The BIOFI project is having collaboration with institutions spread across Switzerland and India. Table 3 gives the list of institutions with their geographical location and the disciplinary contribution

Table3. Institutions by Geography & Disciplinary Contributions – 'Biotechnology Package Project'

Institution	Institution Focus	Disciplinary Contribution
Botany, University of Basel, Switzerland (BIB)	Academics and Research	Biotechnology, Crop Physiology
Research Institute of Organic Agriculture, Switzerland (FiBL)	Academics and Research	Environmental Science, Economics
Bern University of Applied Sciences (HAFL)	Academics and Research	Social science
Bharathiar University, Coimbatore, India (BU)	Academics and Research	Soil Microbiology
Pondicherry University, Puducherry, India (PU)	Academics and Research	Soil microbiology
International Crop Research Institute for Semi Arid Tropics, Hyderabad, India	Academics and Research	Crop Physiology and Plant breeding
M. S. Swaminathan Research Foundation, Chennai, India	Research and Development	Soil microbiology, Agronomy & Social science (Gender,

		Agricultural Economics)
University of Agriculture Sciences, Bangalore, India	Academics and Research	Agronomy

Research Locations: (Study Location-Maps will be inserted later)

The paper draws inferences from the project experience from the 'SCF Project' case study location in Tamil Nadu, India. In Tamil Nadu, the project was implemented in Kannivadi region of Reddiyarchathram block in Dindigul District. This is a semi-arid agro-ecosystem, where farming is largely rainfed. The major crops in the region are cotton and maize, grown during during September to December (North East Monsoon season). The region has almost 80 percent of marginal and small farmers (having less than 2 ha of land). MSSRF has a site office in the region and is operating an Agro-Meteorological Field Unit (AMFU) in the region linked with Indian Meteorological Department to provide medium range weather forecast to farmers.

The study locations for the second project described in this paper are located in the states of Tamil Nadu and Karnataka. The study site in Tamil Nadu is Kolli Hill region of Namakkal district. This is a semi-arid hill agro-ecosystem where farming is rainfed. Majority of the population belong to the *Malayali tribe*s. Their major source of livelihood is farming and most of the farmers are marginal and small farmers. This region was traditionally a subsistence agriculture belt with predominance of millets but the last 2 to 3 decades has seen the cultivation of commercial crops like tapioca, coffee etc. Millets now are relegated to subsistence status and is taken in small plots of land. Millet based subsistence farming is managed largely by women farmers of the household. Millets are taken in mixed cropping systems along with other cereal and legume crops. Produce from these mixed plots are used for household consumption.

The study site in Karnataka is in Mandya district. Mandya district is a semi-arid agro-ecosystem with large parts of it being purely rainfed. The district receives irrigation from the Krishnaraja Sagar Reservoir on the Cauvery river. The major crops in the district are finger millet, sugarcane, coconut and paddy. Finger millet is cultivated in the rainfed parts of Mandya. But in contrast to the Kolli Hill region, finger millet here is taken in mono-cropping systems. And unlike Tamil Nadu, finger millet is still a predominant staple crop in Karnataka. Finger millet cultivation in Karnataka receives subsidised input support from the Department of Agriculture that are distributed through 'farmer service centres' located at '*mandal*[vi]' level. The region has mixed social groups with forward caste and backward caste groups being dominant.

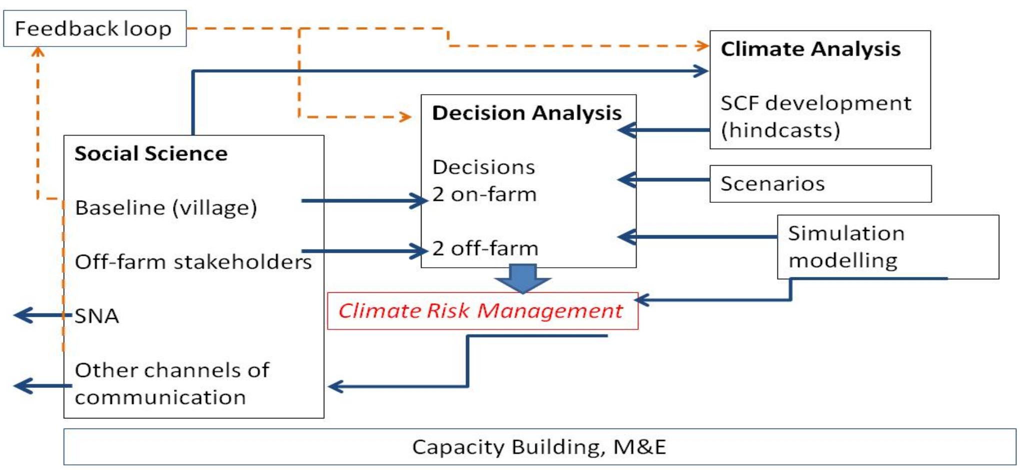
The studies differ widely in terms of the technicalscience partners experience in engaging in interdisciplinary endeavours and the level and nature of intended collaborations. Hence a comparative analysis of these two case studies in which the authors were involved as social scientists gives rich and diverse insights for appropriate planning and designing of similar interdisciplinary research endeavours.

The Case Studies:

Case Study 1: *Can seasonal climate forecasts improve food security in Indian Ocean Rim Countries in a variable and changing climate***?**

The project on ‘climate information product for risk-reducing adaptive actions across agricultural value chain’ was testing the usefulness of SCF information for strategic decision making by players across the value chain in semi arid tropics. As mentioned earlier, the SCF project team consisted of disciplines viz., climate modelling, agronomy, communication and social science (economics, sociology and gender). Points of integration of the different disciplines are as depicted in Figure 1. The climate modellers among the climate science team were engaged in developing the product – that is SCF for the study region. The crop modellers/agronomists among the Climate Science team applied SCF in crop simulation models like DSSAT and APSIM[vii] to predict the outcome of the different decision scenarios. The role of communication team was to develop tools to communicate the complex climate information to the target community.

Figure 1**.** Schematic of integrating different themes in the SCF project



Source: Project Document – Can seasonal climate forecasts improve food security in Indian Ocean Rim Countries in a variable and changing climate?

The social science team consisting of gender, agricultural economics and social network analysts were engaged in informing the climate science and communication team of the socio-economic context of the study region, the farming practices, the extent and nature of use of weather/climate information by players across value chain, the nature and type of climate information that the target community has access to, gendered perception of the farmers on the degree of usefulness of this information, the expected modifications and degree of accuracy, the requirement in terms of climate parameters, and lead times in which climate information would be useful for strategic decision making by actors across the value chain. The social science team used a combination of quantitative and qualitative research methodologies. Quantitative baseline information collected through structured household interviews was complemented with qualitative data from participatory rural appraisals (PRAs). The PRA tools used were focus group discussion, key informant interviews, trend analysis, seasonal and crop calendar, gender analysis matrix, timelines and institutional analysis.

The social science team worked in close collaboration with the communication team in developing products by simplifying complex climate information with the use of decision tools. The social science team was also engaged in building the capacity of the target community to interpret and use the complex climate information to base strategic risk-reducing decisions in the respective enterprises. The capacity building was taken up through interactive workshops where the participants simulated real field decisions using decision analysis tools on the basis of the climate information provided to them. The team also through its gender sensitive social network analysis mapped out the most efficient network for information dissemination in the study regions and also identified the key communication nodes within the network.

The communication and climate science disciplines also invested time and resources in building the capacity of the social science team in understanding and communicating SCF. Intense workshops on understanding climate information of probabilistic nature as well as on using the different 'decision analysis tool' for communicating probabilistic forecasts were organised for the team members. In these workshops, social science team members simulated probable decision choices and mapped it out using the different decision analysis tools. This helped the team members across disciplines to have hands on experience in the benefits and challenges of using these tools and come up with solutions for simplifying the tools.

Process of Integration of the disciplines: SCF Project Experience

The baseline study conducted by the social science team generated great deal of information to help inform and direct research of the climate science team. The most important contribution of the social science team was in redefining the strict definition of seasonal climate forecasts as propounded by climate science and the flexibility it effected in terms of the lead times of the SCF's developed by the climate science. The project document defined seasonal climate information as climate information that is available at least 6 months before the commencement of the season. However the study done by social science team shows that seasonal climate forecast which has a lead time of 3-6 months did not have much relevance for the farmers in the case study village. None of the respondents asked for forecast with 3 month or more than 3 months lead time. This was in contrast to the original conceptualisation of seasonal climate forecast in the project document, as forecasts that are given 6 months before start of season. Further, the study found that different players across the value chain require seasonal climate information at different lead times. The agriculture extension agencies required the information at least 3 months before the season to help develop their agricultural plan for the region. The lead times ranged from 1 month before the season for the farming community to 6 months before the season for the wholesale dealers of multinational input companies. The difference in required lead time across the value chain was indicative of the minimum lead time of climate information that would guide or be useful in strategic decision making by players across the value chain.

A second key result from the baseline study was the documentation of the communities' perception of climate parameters of key importance for their livelihoods. The original idea of the climate science team was to generate forecasts for total rainfall for the season alone as this was identified as the key climate parameter influencing decision making in rainfed farming systems. But the results of the social science study indicated that information on temperature, distribution of rainfall, onset of rainfall are as important as rainfall for basing strategic decisions under rainfed farming systems. More than 50 percent of respondents expressed the need for more parameters apart from quantity of total rainfall during the season.

The third point is regarding access to and communication of climate information to different sections of farmers. In the past they heavily rely on traditional knowledge and there were few knowledgeable members in the village who share the information among men and women farmers through informal networks. In the changing socio economic and climate context the dependence on such knowledge and number of such knowledgeable farmers in the village are declining. Hence Social Network Analysis (SNA) was carried out to understand the current pattern on communication among them and the results showed that there is a wide disparity between men and women in terms of access to weather and climate information as well as general farming related information among the community in the study region (Galliard *et al*.,2014). This disparity was also witnessed across size classes of farmers irrespective of gender. It was noticed that larger farmers had more access to and in some instances monopoly over official channels of communication with respect to all farming related information. The major official channel of dissemination of weather information in the case study regions were mass media like television, radio, newspaper, the agro-advisory bulletins generated by the respective Agro-met Field Units (AMFU) of Indian Meteorological Department (IMD) and disseminated through Department of Agriculture, other relevant line departments, and the Farmer Producer Organisation (FPO) in the region through its network of Village Knowledge Centres (VKC's). The informal network of weather information dissemination was through the small group chats at tea shops, in panchayat offices, and other common places of social interactions.

The SNA results show a clear overlapping of the informal and formal network in one of the case study village. According to the community, the informal network was more effective than the formal network as what gets discussed in the informal network is not only the forecasts, but also about activities that can be planned following the forecasts. Though the agro-advisories generated and disseminated through the formal network too have this kind of weather forecast based advisories, the reach of this was much less compared to the informal network. Moreover, the agro-advisories disseminated through the formal network were more generic in nature and for the district as a whole. Farmers bestowed a higher level of trust on the farming suggestions coming from fellow farmers in the informal network than those in the agro-advisory bulletins from the formal network. It was found that in villages where men and women marginal and small farmers were members in Farmer Producer Organisations (FPOs), the level of access to farming related information- weather, market, inputs etc- were higher compared to villages where FPOs were absent. This was evidenced in the difference in nature of the social networks that emerged from the case study villages, namely Pudupatty and Konur. The social networks that emerged from

Pudupatty village, where marginal and small farmers were members of FPOs, were found to be more robust and dense compared to Konur village, where FPOs were absent. The robustness and denseness of the social networks are indications of extend of flow of information within the village community.

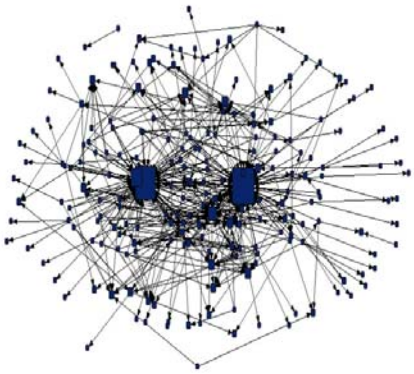


Fig 2. Weather and Climate Related Network for Pudupatty Village, Source: Galliard *et al*., 2014

Moving further on from the science team was engaged in communicating seasonal cli ommunity. In this activity, the Social science team worked in close collaboration with the communication team. Issues with communicating seasonal begin with, this was information that was prob chances of occurrence of an event. Probabilistic climate information was a novelty in the region as the officially disseminated weather information was deterministic in nature. Added to this complexity of the information, the communication tool 'decision tree' which was used to communicate the information had issues in terms of being difficult to understand for people with not so much of formal education. It was found that the tool was of use only for players at the higher end of the value chain. When this was shared with the communication team, they came out with modified and simpler graphical versions of the 'decision tree' like 'decision graphs' and 'wonderbean' for use with the farming community[viii].

The results that emerged from the studies conducted by the social science team informed many of the project interventions and helped achieve meaningful project outcomes through refining the project processes and making the project process accommodative of the differentiated needs of the spectrum of stakeholders the project engages with. The next section provides insights on the process of disciplinary integration across project processes and outcomes.

Integration Effected at redefining Research Concept, Process and Output Level:

The results of the social science team were debated at length at join project partner team meets. The climate science and communication team showed a great degree of openness in learning from the social science theme about ground realities and making necessary changes to the project at the conceptual, process and output level. The joint partner meetings were forums for cross fertilisation of disciplines. The communication and climate science disciplines also invested time and resources in building the capacity of the social science team in understanding and communicating SCF. Intense workshops on understanding climate information of probabilistic nature as well as on using the different 'decision analysis tool' for communicating probabilistic forecasts were organised for the team members. In these workshops, social science team members simulated probable decision choices and mapped it out using the different decision analysis tools. This helped the team members across disciplines to have hands on experience in the benefits and challenges of using these tools and come up with solutions for simplifying the tools. Owing to this two-way process of sharing and learning the following changes and integration process was initiated across the thematic disciplines:

- Stress of defining seasonal climate forecasts shifted from being 'climate information at least 6 months before commencement of season' to 'climate information at least 1 month before commencement of season'. Accordingly, the climate science team also worked on their climate models and generated seasonal climate information with varying lead times ranging from 1 to 6 months to cater to the demands of the target community.
- Developing and providing forecast for the additional climate variables
- Mapping of the information dissemination network helped design and build climate information dissemination networks aimed at maximum reach.
- The climate science and communication team in partnership with the social science partners packaged the products in the increasing degree of their simplicity based on feedbacks received from the experience of social science partners on the ease and effectiveness of the tools in communicating the complex climate information. For example the decision graphs[ix] and wonderbean[x] tools which had elements of graphical representation combined with tabular inputs replaced the purely tabular form of decision tree.

Case study 2: Biofertilization and "bioirrigation" for sustainable mixed cropping of pigeon pea and finger millet (BIOFI)

The project aims at development and implementation of an environmentally and economically sustainable finger millet and pigeon pea intercropping system for arid/semi-arid zones, using biofertilisers to augment the process of bio-irrigation for this specific intercropping combination (Project Document)[xi]. The complicated mission statement of the project warrants an explanation of the science behind the innovation for non-science background audience to understand what the proposed product is all about and what the product is capable of achieving in the field. In simple terms, the basic principle underlying the project is that pigeon pea and finger millet when grown in an intercropping system with introduction of a specific combination of biofertilizer will have enhanced productivity through biofertilisation as well as through the process of bioirrigation. The combination of biofertilizer and plant that facilitates bioirrigation is Arbuscular Mycorrhizal Fungi (AMF) and pigeon pea. AMF when applied to the soil creates a sponge like network around the roots of pigeon pea as well as fingermillet. The unique characteristic of pigeon pea is that it is a deep rooted plant and through its combination of deep tap root and lateral roots as well as the network of AMF it absorb water and nutrients from deeper layers of the soil supplies it to the sub-soil surface. And in the presence of the AMF the raised water spreads horizontally and supplying water and nutrients to the adjacent shallow rooted finger millets.

The principal output of the project is a "package" consisting of seeds for mixed-culture and compatible strains of biofertilizers of local origin suited for rainfed and saline fields in South India. The proposed outcome of the project is climate-resilient sustainable pigeon-pea and finger millet intercropping system, an unique combination of biofertilisation and intercropping to facilitate bio-irrigation, in drought prone semi-arid rainfed ecosystems. This system would be easily adoptable by marginal and small farmers and is expected to increase their coping capacity to unexpected intra-seasonal short dry spells. Upscaling of this 'biotechnology package' is envisaged through the promotion of 'eco-enterprises' (to mass multiply the necessary strain of biofertilizers) operated and managed by marginal and small men or women farmers. Such decentralized production of biofertilisers is aimed at addressing challenges in technology access for the marginal and small farmers. Decentralised production of biofertilisers makes it available locally as well as assures ownership and control of this technology for the local men and women farmers. A basic assumption underlying the project is the prevalence of finger millet-pigeon pea intercropping systems across semi-arid ecosystems in South India.

The major collaborating disciplines are technical sciences such as microbiology, soil science plant physiology and agronomy with social science (sociology, gender and economics). The role of the microbiologist is to isolate, identify and characterize AMF and PGPR strains most suitable to the study regions. They would also assess the impact of biofertiliser application on soil biological properties. The soil scientists are involved in studying the physical and chemical properties of the soil, while the agronomists are associated with identifying suitable varieties and cropping systems, whereas the plant physiologists and breeders are studying the bio-irrigation vis-à-vis different pigeon pea varieties. 'Life cycle assessment' is carried out to compare the efficiency of the mixed cropping scheme of the conventional farmer's practice in aspects like land requirement, energy consumption and water use by the economics team. Social science team consisting of agricultural economics, gender, and sociology were responsible for baseline studies on input, farming practices, adaption behavior, market study and studying the economic viability of the BIOFI package.

In the early phase of the project, the role of social science team is to carryout baseline study to understand the seed systems, farming systems, intercropping pattern, input procurement behavior and innovation behavior of men and women farmers in the study region. The aim of conducting baseline as articulated in the project document was to adapt and fine-tune innovations to the context and requirement of resource-poor farmers in the study region. Social science team would also extend support to the microbiologists in operationalising the local production of biofertilizers technology by refining the production process with the participation of local farmer groups. The other important role of the social science team is to field test the BIOFI package evolved by the technical science with the participation of farmers and assess the economic viability of the package.

An interesting aspect of this project is the direct engagement of the farmers in conducting field level demonstrations along with researchers and also their engagement in customizing the technology package. This approach allows for conducting field experiments jointly by the farmers and researchers. As an outcome of this process, mass multiplication of biofertilizers and seedlings of pigeon pea in poly bags are produced by farmers themselves.

Process of Integration of Social science and TechnicalScience: Biotechnology Package Project Experience

Social science team conducted detailed baseline studies on finger millet, pigeon pea cropping system, farming system, seed system, and innovations in both the case study sites. The results of the baseline studies gave very interesting insights. Majority of the results were found to be in contrast to the assumptions of technical scientists with respect to the cropping system prevalent in the agro-ecosystems chosen for piloting the package. The package will be effective only if a combination of fingermillet and pigeonpea cropping systems exist in the field. The system combination being, the presence of finger millet and pigeon pea in a row intercropping system, where the crops are taken in a ratio of 4:1, that is for 4 rows of finger millet and 1 row of pigeon pea and practice of applying bio-inoculants.

The baseline study conducted by the Social science team showed that the farmers practice in the study sites chosen for implementing the project to be quite different from what is described in the project as ‘necessary aspects for success of the BIOFI project’. In one of the study sites, Kolli Hills of Namakkal District, traditionally the finger millet is taken in mixed cropping systems but are not line sown. Finger millet accounts for 80 to 90 percent of total area under mixed crops in a field. The remaining percentage is covered by other short statured legumes and cereals. Pigeon pea was very thinly found in this finger millet based mixed cropping system. Pigeon pea, if present is sown in borders or in very wide distances in the mixed cropping plots. Hardly, 3 to 4 plants of pigeon pea could be counted in plots where pigeon pea was said to be present in 40m2 area. The farmers especially women, had very valid explanations for not taking pigeon pea along with finger millet. They said, pigeon pea grows very tall and has spreading foliage, which gives shading effect to finger millets. The shade of pigeon pea is detrimental for the growth and yield of finger millet, if it is grown in equal densities.

Another challenge in the cropping system for the diffusion of the package was the absence of line sowing practice in finger millet or pigeon pea. Finger millet and other millets and some of the legume seeds were mixed together and broadcasted. Pigeon pea was placed randomly in the field, in such a way that there is minimum population of pigeon pea to finger millet and other crops in the mixed crop field. Finger millet based cropping system in Kolli Hills was a subsistence system with women farmers playing the key role. The system being subsistence is less resource intensive and hence external fertilisation or pest and disease management through use of pesticides were absent. Moreover, broadcasting was done and this method of sowing requires less labour in contrast to line sowing.

In the other study site, Mandya District of Karnataka, finger millet is largely grown as sole crop. While in a mixed cropping system, they are taken with short statured legumes like lab lab and cowpea. The other predominant crops in the mix were niger and sorghum. Line sowing, in fact transplanting of finger millet was a common practice in this study site, but here again the challenge was finger millet and pigeon pea were hardly grown as intecrops in the same plot of land.

The other key element in the biotechnology package, namely the biofertilizer is also expected to face a similar challenge. Almost none of the farmers in the region have even heard of biofertilisers, let alone use them. The level of access to knowledge and innovations was found to be very low among the farmers across class and gender. And the few who said had used it at one or the other point of time, said they used it on crops other then finger millet or pigeon pea. Mostly it was horticultural or plantation crops and the source of biofertilisers were government schemes which were specific to these crops.

The results when presented to the larger partners got mixed reactions. Few members said the sites were wrongly chosen as they felt these findings are specific to these sites alone, and the rest of the finger millet growing places in the respective States had pigeon pea as an intercrop. Some of them in the technical science team sharing the surprise of the rest of the members at the result, were at the same time open to accommodating the results rather than outright rejecting it. Several of them took it as a learning to do a detailed pre-project field study before the launch of any project. This reiterates the importance of dialogue and cross learning between the different disciplines engaged in an interdisciplinary project for better planning, implementation and for realising better project outcomes.

The more open among the technical science group partners also suggested having a rethinking on the crop combination, namely growing lab lab instead of pigeon pea in combination with finger millet. This was more owing to the findings of the social science team of the presence of lab lab, a deep rooted legume, in the finger millet based mixed cropping system in both the case study locations.

The baseline questionnaire also contained questions on whether the respondents would be willing to adopt the new sowing practices suggested in the BIOFI package, namely, 1) line sowing of finger millet and pigeon pea and 2) pre-culturing pigeon pea in polybags and 3)transplanting pre-cultured pigeon pea. Almost 50 percent of the respondents had replied in the affirmative on this, giving some hope to taking the intervention forward to the farmers, on a pilot basis through on-farm trials with farmers who expressed willingness to do it. Thus, 12 farmers (7 women and 5 men farmers) have been selected from the baseline from one of the study sites, Kolli Hills, for participation in the on-farm field trials.

A key positive outcome of the social science study in the projects has been rethinking by the technical science team on the design of the on-farm trials in the project. Moving away from the prescribed rigid protocol which was developed on the basis of the ‘field trials’ conducted by the BIOFI partners, the revised on-farm trials have been designed taking into account the field reality in the respective sites. The new design incorporates farmers practice as a check, and in the farmers practice introduces the package one step at a time, starting from inoculation with bio-fertilizers at different levels and finally planting of pigeon pea pre-cultured in polybags inoculated with biofertilisers. This protocol was further refined and finalized after discussion with men and women farmers in the study region. In addition to the relaxation on the design of the field trials, the biotechnology partners are also debating as to experimenting with a new crop combination like lab lab - which is already taken as a mix with finger millet by farmers in both the case study sites- to assess biofertilisation and bioirrigation.

Implications for Gender in the Case Studies:

In both the projects, the inter-sectoral approach adopted by the social science team in the research gave insights into the differences in challenges and opportunities in livelihoods across different size classes and sex of the farmers. The baseline data collection and analysis was done in a gender sensitive manner along with inter-sectoral social, economic and demographic variables like class, caste, gender (women's marital status) and age. Results of the baseline studies were presented adopting a gender-sensitive framework.

In SCF project, the gender differential needs of women and men farmers in lead time, access to forecast information and level of decision making were studied. Based on the results capacity building programmes were planned for the men and women farmers on SCF (to understand and use probabilistic climate information)and institutionalised the forecast through Farmer Producer organizations. In case of BIOFI project, the predominantly women farmer managed subsistence cropping systems of finger millets in one of the case study sites pose a serious challenge in the project. The package will be introducing a series of technologies which are hitherto alien to the cropping system in this region namely, 1) line sowing of finger millets, 2) intercropping of finger millet with pigeon pea 3) pre-culturing pigeon pea in polybags 4) transplanting pre-cultured poly bags of pigeon pea and 5) application of bio-inoculants. The research team has to take these factors into account and work out possibilities of redesigning the package to make it easily adaptable by the resource poor subsistence farmers, especially women farmers in the region.

Reflections on Interdisciplinary Research Partnerships:

Experience from the two different interdisciplinary projects have shown that the factors determining effectiveness (in terms of resulting in desirable outcomes) of the interdisciplinary collaboration largely depends on 1) the conceptual clarity in the overall research document regarding the role and point of integration of the different disciplines, and 2) process undertaken to bring about such integration and 3) personal characteristics of individuals leading the different disciplines (Birnbaum, 1977; Likens, 1998).

Issues of Conceptualizing:

Interdisciplinary research is not just about researchers from different disciplines coming together and sharing their outcomes or data, but about sharing different perceptions across disciplines and gaining an integral understanding about the issue being researched (Iokiñe et.al. 2009**).** For this to happen, any interdisciplinary research should have a clear conceptual framework explaining the points of integration as well as the feedback loops across the disciplines. What worked in the 'SCF Project' was that the researchers from different disciplines through a participatory process had clearly defined and developed a schematic for integration of different disciplines. There were sincere efforts at incorporating the research outcomes across disciplines and modifying concepts and processes to be as adaptable to field reality. In the BIOFI project, partners were of the view that social science has limited role in shaping the technology in a purely technology oriented project and their role lies in diffusion of technologies among farmers. Initially the research outcomes of the social science team were looked upon as clash of opinions with the assumptions in the projects. But over the period of close interaction (second year of the project) and working together in on-farm trials in farmers field provided opportunities for both the team to come together understand each others concern and work together for a common goal. The flexibility effected in the design of the participatory on-farm trials including conventional farmers practice as control and slowly adding complexities of technologies in the BIOFI package could also be considered as a positive step in this direction.

In brief, the experiences from these two participatory action research projects indicates that the disciplinary cooperation between both the teams has supported to go deeper in their disciplines to address new challenges from the technology user's perspective, that otherwise would not have been thought off when it is implemented independently. The partnership on interdisciplinary approach resulted in reformulating the research assumptions and questions of the technical scientists. Similar observations were recorded in Ghana by Adjei Nsiah *et al.,* (2004) while working among migrant and native farmers on soil fertility management practices and reiterated by Paul Smolensky (2000b). With reference to research methods, the team followed the methods which are appropriate to the problems in the respective projects and gave much importance to processes, dialogue and consultations to arrive shared understanding.

Characteristics of Interdisciplinary Teams and position of social sciences in the collaboration:

In an interdisciplinary research team, over and above the disciplinary base, personality of the collaborators and leaders play a significant role to get the desired results. Interdisciplinary research teams are best led by people who themselves have a strong interdisciplinary background and show interest in a wide range of subjects. Respect for other disciplines, willingness to understand and promote success of other disciplines is other essential leadership traits for successful interdisciplinary collaboration (Bruce *et al*., 2004). Earlier studies done by Lyall and Meagher (2007) and Lyall and Tait(2007) also indicated that the collaborators in an inter-disciplinary team need to be open minded, willing to learn from other disciplines and appreciate the research methods and cultures of the different disciplines. Position of the researchers representing different disciplines, communication systems and shared understanding on the research issue and framework among the consortium team are fundamental for the research partnership. In both the projects social science component played a significant and important role in facilitating the research process and had equal status in the project. On these line, Bommer's (2013) work also suggested three basic principles for interdisciplinary research as "ensuring that all research partners have equal status in order to neutralise power differences, need for a close working relationships among research partners and those in a position to implement findings and have a common language and problem definition before starting any investigation".

In both the projects, partners from social science team had strong interdisciplinary base and they anchored the important part of the action research component i.e interfacing with farmers and researchers. However the position of the social science team within the consortium is the most crucial factor, in case of SCF project, the social science team was in 'steering approach' position (Van Dusseldorp, 1977; Van Dusseldorp and Box, 1990) in which they played a crucial role in defining the research problems to improve the uptake of climate information and influence the direction of research of other disciplines (climate science and communication). Whereas in BIOFI project, the project is started with an 'accommodation approach' in which technical science team define what kind of technical innovations are possible and on that basis social science team make an assessment. Here in this case microbiologists and agronomists decided the microbial interactions and cropping systems in improving the productivity and later social science team had made an assessment on the social, economic and cultural aspects of the practices.

Several of the science researchers in the 'SCF project' had a great degree of experience engaging in research of the interdisciplinary nature. While in case of the 'BIOFI project' was the new attempt by the bilateral network to initiate the spirit of interdisciplinary research in a hitherto 'science only' research partnerships promoted by the bilateral network.

Conclusion:

This paper is an attempt to capture the process and outcomes of collaborations between technical science and social science in two multi partner interdisciplinary research projects in which the authors were involved. An important takeaway from the project experiences is the reflections on the factors that determine the success in terms of desirable research outcomes of an interdisciplinary collaboration. The project experiences highlights 1) a clear conceptual framework explaining the points of integration as well as the feedback loops across the disciplines, 2) well defined roles and responsibilities of the collaborating disciplines, and 3) mutual respect, as must haves, and in addition 4) Interdisciplinary research/experiential base of individuals engaged in the partnership 5) process based orientation of research partners and 6) position of social science partners in the consortium are vital for an interdisciplinary research partnership to deliver desirable outcomes.

Clash of opinions between disciplines is not to be looked upon as hindering research, but as opportunities to open up new ways of thinking about research problems and opportunities for future research. In both these research studies the interdisciplinary cooperation between social and technical scientists helped to sharpen and improve the relevance of 'disciplinary' research questions and framework to the local context. This in essence is what is conveyed by the quote from '*The Structure of Scientific Revolutions' by Thomas Kuhn,* found at the beginning of this paper.

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End Notes:

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[i] Dr. Paul Smolensky, *Interdisciplinary Challenges in Cognitive Science', In Workshop on Bridging Disciplines in the Brain, Behavioral, and Clinical Sciences, National Academies Committees.*

[ii] According to Dusseldorp and Wigboldus (1994), defines narrow and broad interdisciplinary based on the number of collaborating disciplines as well as research partners background, in case of broad interdisciplinary form wide range of disciplines are involved from technical to social disciplines.

[iii] Detailed project title for project 1" *Can seasonal climate forecasts improve food security in Indian Ocean Rim Countries in a variable and changing climate*?" and project 2 is "Biofertilization and "bioirrigation" for sustainable mixed cropping of pigeon pea and finger millet (BIOFI) are given later on in the paper**.** For convenience the two case studies will be referred to as indicated in brackets.

[iv] Decision Science deals with decision theory. Decision theory is defined as the broad spectrum of concepts and technology which have been developed to both describe and rationalise the process of decision making - that is making a choice among several possible alternatives. Decision Science is being offered as part of Business Administration degree in academic universities like University of Texas and Carnegie Mellon University.

[v] Men and women farmers and other actors in the agricultural value chain ranging from input dealers to marketing agents, and the support services like agricultural extension, credit and insurance.

[vi] Mandal is an administrative unit smaller than the taluk and bigger than the panchayat

[vii] **D**ecision Support System for Agrotechnology Transfer (DSSAT) and Agricultural Production Systems sIMulator (APSIM) are crop simulation models that cover a range of plant, animal, soil, climate and management interactions.

[viii] Decision tree are excel spread sheets allowing for different layers of decisions to be accommodated and presented on rows and columns of the spreadsheet. This requires the respondent to articulate, allocation choices, varietal choices, crop management decisions, the cost, the potential yield and the expected revenue for each of the choices made.

[ix] Decision graph is a graphical representation of outcome of the decision tree. But as in decision tree, respondents are expected to articulate layers of decisions to arrive at the outcomes. Hence decision graphs also require complex calculations as decision trees. The advantage of this tool over decision tree is that it helps the respondent to see the outcomes of the alternate choices immediately on the graph, and it has less decision layers through which the respondent has to travel to get the outcome.

[x] Wonder bean is also graphical, but it is much simpler compared to decision graphs. In wonder-bean, respondents are required to articulate just one decision choice, namely, proportion of land allocation between the farmers staple and the 'wonder bean' given the information on the upcoming season. The respondents are not required to take up complex calculations to map out decision outcomes. The calculations are inbuilt in the tool and is done automatically once the land allocation decision in made by the respondent.

[xi] The first paragraph draws heavily from the project document and the interaction with Dr.Prabhavathy, Principal Scientist (Microbiology) M.S,Swaminathan Research Foundation

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