Transdisciplinarity as an emergent property in an agricultural research for development project

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Abstract: An agricultural research for development project on the East India Plateau is analysed retrospectively using a conceptual model for transdisciplinary research. The analysis reveals strong similarities, and some marked disparities, between project practice and the conceptual model. Transdisciplinary characteristics of the research project include:

- Participation of scientists (hydrologists, agronomists, animal scientists, agricultural economists) and non-scientists (farmers, development professionals) in the research process.
- Integration of research activity and results across discipline boundaries.
- Deliberate creation of learning experiences as a consequence of participation in the research process.
- Application of research results in formats useful for the practices of farming, development, and science.

The most marked discrepancy between the project and the conceptual model was the inadequate development of a shared understanding of the transdisciplinary research process, including clarity around boundary issues. The significance of the conceptual model for ongoing project research and emerging research opportunities is discussed.

Keywords: Farming systems, rural livelihoods, poverty alleviation, nutritionally sensitive agricultural interventions, development praxis

Introduction

An agricultural research for development project in rural east India is improving livelihoods for indigenous farmers. The project focusses on intensification and diversification of cropping systems through a process of farmer engagement around livelihood improvement based on Self Help Groups (SHGs). Agricultural/horticultural interventions are selected after consultation with villagers and implemented with farmers as on-farm research activity. The research activity provides learning opportunities for participating farmers as well as generating research results under local farming conditions. In addition to research into new agricultural technology and systems, the project has a strong focus on research into the process of farmer engagement and the process of scaling out project innovations.

Project research activity addresses several current international priorities in agricultural research for development such as; sustainable intensification of agricultural production (Garnett et al., 2013), agriculture for nutrition and health (Remans et al., 2011), climate resilient agriculture (Neufeldt et al., 2013), and gender responsive agricultural research (Beuchelt & Badstue, 2013). Donor organisations are seeking evidence-based interventions supported by measured impacts against key indicators. With this in mind, the current project is devoting significant resources to measuring impact of project interventions on key indicators such as farm productivity, household income, nutrition security, and the status of women.

There is emerging agreement that sustainability challenges require new ways of conducting research so that research outcomes are more relevant to societal needs. For example, greater participation of farmers and development professionals should lead to greater relevance and impact of agricultural research interventions. Transdisciplinarity is used in this paper following the definition of Lang et.al (2012).

> *"Transdisciplinarity is a reflexive, integrative, method driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge."*

A conceptual model for transdisciplinary research processes (Lang et.al, 2012; Jahn, 2013) is applied retrospectively to the process of project conception and implementation. This analysis reveals some strong similarities, but also some disparities, between the conceptual model and project practice. The usefulness of the conceptual model is discussed in the context of ongoing project research and several emerging research opportunities.

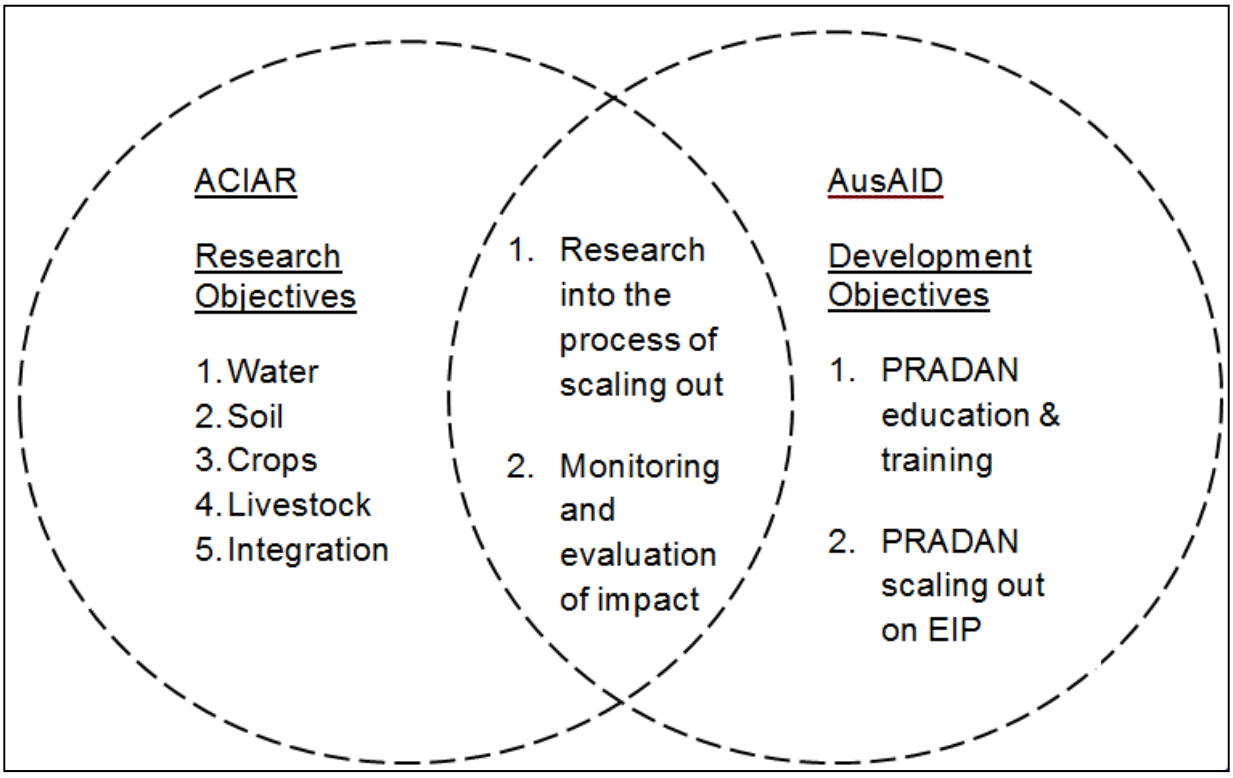
Synopsis of the agricultural research for development project

The project is located on the East India Plateau, working with tribal communities in the states of Jharkhand and western West Bengal. The area is one of the poorest areas in India (OPHI, 2013) and in these communities poor nutrition is the major contributor to the OPHI Multidimensional Poverty Index. The region is characterised by high but variable rainfall (1,100-1,600 mm, 80% June-September), frequent and sometimes long dry spells within the monsoon, little irrigation (~8% of area), high runoff and soil erosion, and subsistence agriculture. Rice is the staple food crop, and traditional cropping systems are based on a mono-crop of transplanted rice. Population pressure has pushed rice cultivation onto the medium uplands, but these lands are poorly suited to traditional paddy (transplanted) rice production systems (Cornish et al., 2010).

The agricultural research for development (AR4D) project *"Improving livelihoods with innovative cropping systems on the East India Plateau"* brings together the NGO Professional Assistance for Development Action (PRADAN) with several research organisations; University of Western Sydney (UWS), the World Vegetable Centre (AVRDC), and Advanced Centre for Water Resources Development and Management (ACWADAM). The project embeds agricultural research within a wider development project (Figure 1) combining research objectives, development objectives, and research into the development process. Agricultural research is conducted with active participation of local farmers, utilising Self Help Groups (SHGs), with deliberate promotion of the role of women as farmers.

Agricultural research is focussed on sustainable intensification of cropping systems. The traditional mono-crop of transplanted rice is being replaced with a more climate resilient cropping system featuring aerobic (non-transplanted) rice and a range of profitable vegetable crop options. The new cropping systems are more productive, profitable and make better use of land and water resources. Research interventions are nutritionally sensitive, increasing pulse, oilseed, vegetable, and goat production, increasing household income, and diversifying diets. New agricultural technology is also freeing women from menial labour tasks like transplanting rice and hand weeding. In addition to the agricultural interventions, the project is also exploring the process of farmer participation in the research activity as a development process, and the challenge of scaling up this engagement process.

Figure 1: The project explicitly combines research and development objectives. Agricultural research (Australian Centre for International Agricultural Research, ACIAR funded) and rural development (Australian Agency for International Development, AusAID funded) activity is both distinct and complementary to each other (reproduced from ACIAR project proposal (Bellotti & Cornish, 2012)).



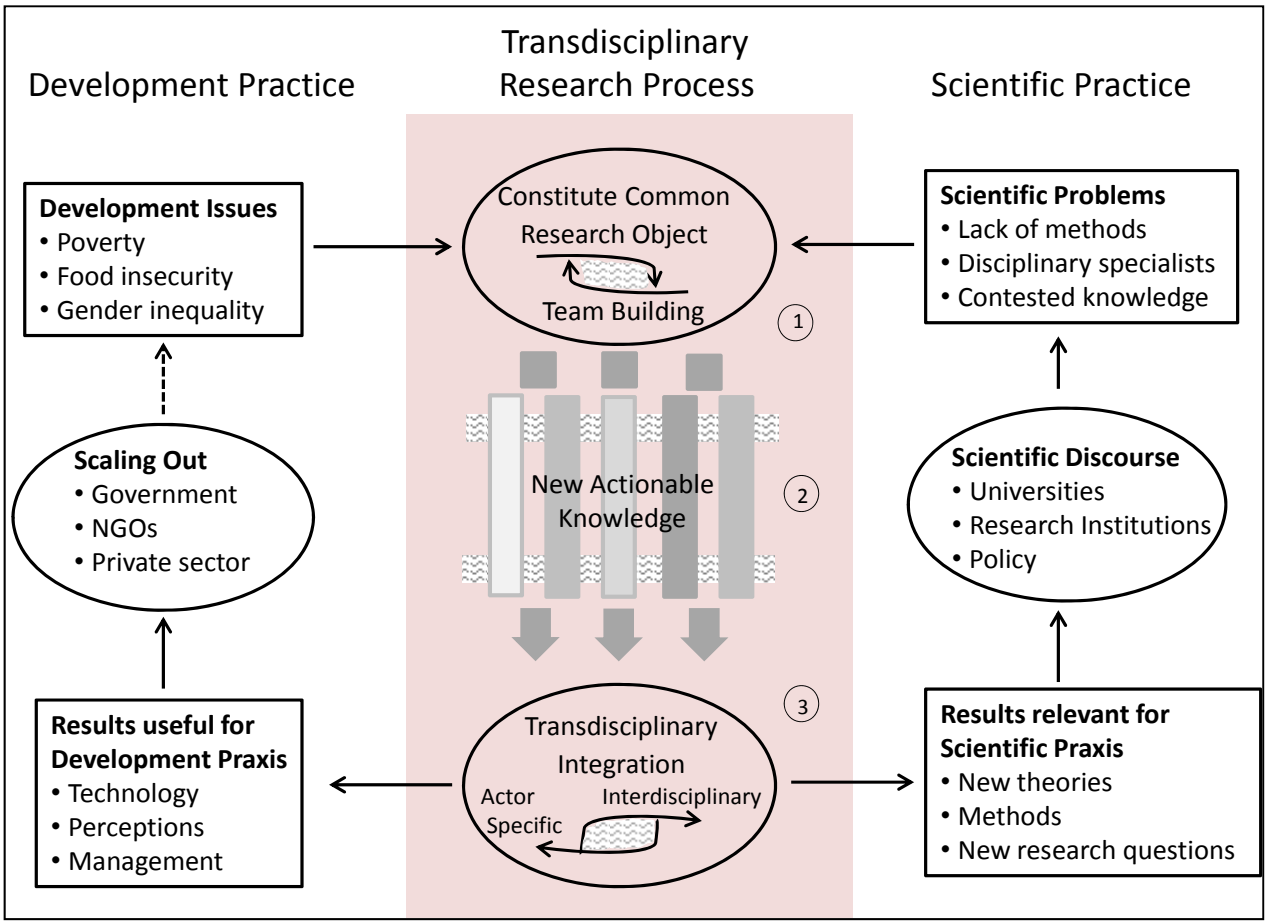
Applying a conceptual model of transdisciplinarity to the project

The author became aware of a conceptual model of transdisciplinary research in 2013 (Lang et. al., 2012; Jahn, 2013), some three years after detailed planning and team building of the current project had commenced. Nevertheless, it is a useful exercise to apply the model retrospectively, to compare what we actually did to what is currently described as good transdisciplinary research practice. In addition, awareness of transdisciplinary practice from other projects will inform on-going project research activity, putting into practice the transdisciplinary principle of iterative reflexive review and planning. What follows is a brief outline of the conceptual model, followed by a description and analysis of project activity in each of the three phases of transdisciplinary research.

A conceptual model of a transdisciplinary research process

A conceptual model of a transdisciplinary research process has been redrawn to more closely reflect the current agricultural research for development project (Figure 2 adapted from Lang et.al., 2012; Jahn, 2013). A defining feature of transdisciplinary research, distinguishing it from multi- and inter-disciplinary research, is the deliberate combining of scientific practice (right hand side) with societal practice, or in this case development practice (left hand side). The current project integrates non-scientists such as development professionals (PRADAN) and small-holder farmers with scientists (agronomists, horticulturalists, hydrologists, animal scientists, and agricultural economists) from universities and research institutions. Each community of practice (development or scientific) has its own issues, problems, opportunities; and each practice can proceed independently of the other to generate results that are relevant to their specific needs. Importantly, each practice also operates under a distinct epistemology that determines, amongst other things, how problems are defined and the utility of research outputs.

Figure 2: A conceptual model of a transdisciplinary research process adapted from Lang et. al., 2012 and Jahn, 2013, to reflect the current agricultural research for rural development project on the East India Plateau. See text for elaboration.



The central column represents the essential features of the transdisciplinary approach, comprising three distinct phases of transdisciplinary research activity:

1. Problem framing and team building. This phase involves the creation of a common research object and the building of a collaborative project team. Different epistemologies and world views need to be made transparent to facilitate the emergence of a consensus problem and research plan. The research plan includes specific plans and methodology for knowledge integration, and plans for the delivery of research outcomes in appropriate formats for different actors. A shared and deep understanding of the research process resulting from this phase is a necessary precondition for success in subsequent phases.

2. Creation of actionable knowledge. This is the phase where the research plan is implemented. Research can be conducted within sub-projects (represented by the vertical bars in the central section of Figure 2) but a core requirement is that research concepts and methods are designed to be integrative (represented by the horizontal bars). Some key features of the research are:
   a. The research involves participation from non-scientists.
   b. Research addresses 'lived reality' of target beneficiaries.
   c. Research outputs are intended to be actionable by specific actors.
   d. Learning can be a planned outcome of the research activity.

3. Integration and application of new knowledge. The defining feature of this phase is the integration of newly created knowledge into either development practice or scientific practice. An important and intended consequence of participation of non-scientists in the research pro-

cess (phase 2 above) is the creation of intense learning experiences. Such experiences have been identified as an important element of a designed intervention aimed at epistemic development (Bawden, 2007), which in turn forms the basis for behavioural change. These experiences can have profound and lasting impacts on all participants, scientist and non-scientist alike.

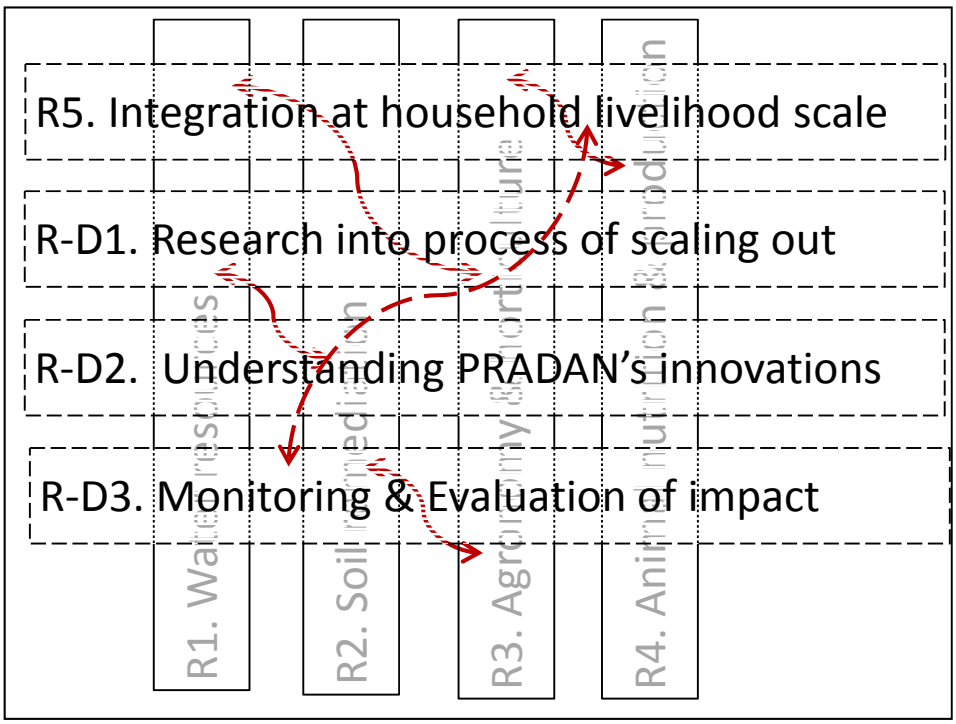
Phase 1: Collaborative problem framing and building a collaborative research team
Although the problem framing and team building for the current project were completed prior to learning about this particular conceptual model of transdisciplinary research, there are some striking parallels with, and also some glaring departures from, what we did compared to the model process. Firstly, the parallel features. The project was conceived as an agricultural research for development (AR4D) project and a key element was the strong presence of PRADAN in problem framing and team building. At the time of project formation PRADAN's mission was broadly focussed on improving livelihoods of smallholder farmers, and recently this has evolved to a focus on facilitating 'a sense of agency' in the poor and marginalised.

At a three day problem framing workshop (held in Jharkhand in September 2010), attended by 27 people representing development professionals and scientists from 7 organisations (but with no direct farmer representation) the potential project team identified the overall project objectives and broad methodologies. These were later drafted into the research and development objectives described in the project synopsis (Section 2, Figure 1). We included several explicitly cross cutting research objectives; namely our focus on integration of research results at the household, family farm scale, the formal Monitoring and Evaluation program, research into the process of scaling out, and research into some of PRADAN's processes for communication and innovation. We also deliberately incorporated learning experiences (particularly focussed on, but not limited to, smallholder farmers) into the participative research process.

So much for the parallels, what about the glaring departures? We were not explicit about this project being a transdisciplinary research process! Some team members were well versed in participatory action research, and some were familiar with transdisciplinary philosophy and methodology, but we failed to bring all team members to a common level of knowledge and understanding. This meant we spent too little attention on why our project was different to 'normal' research processes. The boundaries between scientific disciplines, and between scientists and non-scientists, were not explicitly addressed, consequently the project team did not develop 'boundary objects' (Clark et al., 2011). The project team missed the opportunity to strongly identify a shared research object resulting in a level of confusion among scientists regarding their role and methods. This missed opportunity came to a head with the withdrawal of a key national agricultural research organisation from the project team on the grounds that the project was too 'development focussed'. A future project team workshop will be devoted to exploring how a shared understanding of the conceptual model for transdisciplinary research could clarify roles, responsibilities, and better meet expectations of all team members.

Phase 2: Creation of new actionable knowledge through collaborative research
The implementation of the research process is still in the establishment phase. Some pilot on-farm research was commenced in 2012, and this was expanded in the 2013 kharif (monsoon) season and following rabi (post-monsoon) seasons. The first of three household surveys was commenced in 2013 to provide a baseline for subsequent household surveys planned for 2015 and 2017 that together form part of project M&E activity. The existing project research and development objectives (Figure 1) are redrawn in Figure 3 following the format of the central section of the transdisciplinary research process (Figure 2, Creation of new actionable research).

Figure 3: Project research and development objectives presented in the format of the conceptual model of transdisciplinary research. Project research objectives (R1 to R4) presented as separate discipline and issue based research activities in vertical bars, solid arrows indicate interdisciplinary research activity. Integrative research (R5) and research into development processes (R-D1 to R-D3) superimposed as transdisciplinary research activity in horizontal bars, dashed arrow indicates research activity can cut across objectives.



Project research objectives can be grouped as discipline and/or issue based; for example R1, analysing available water resources (rainfall, stored surface water, residual soil water, shallow groundwater) and presenting this new understanding in ways useful for farmer decision making (e.g. What are my crop options given my available water resources?). There are several planned interactions between research objectives; e.g. R1 (water) is influenced by R2 (soil remediation) and vice-versa. Similarly R3 (agronomy & horticulture) is influenced by, and can influence, both R1 and R2 through bioremediation of soils by crops and through crop water use. These interdisciplinary interactions, and a determination that research should benefit smallholder livelihoods, were designed into the research program during the problem framing phase.

Several research and development objectives cut across the disciplinary research objectives, and are tentatively described here as transdisciplinary research activity (Figure 3). Each of these horizontal activities features strong participation of development professionals and farmers in the research activity. For example, R5 (Integration of interventions at household livelihood scale) requires a deep understanding of the 'lived reality' of smallholder farming and a realistic assessment of project interventions on livelihoods, this can only be achieved through a partnership between scientists and farmers built on trust. Research activities R-D1 and R-D2 relate closely to PRADAN's process of engagement, in particular their facilitation of women's Self Help Groups. Consistent with their long-standing promotion of SHGs, is their more recent focus on facilitating a sense of agency, particularly in women. We are interested to better understand how this is perceived among project members (including women farmers) and how this process of engagement can be effectively scaled out. From the initial conception of the project there was a deliberate focus not just on 'technical' innovations in farm practice, but also 'process' innovations in engagement for livelihood improvement.

Phase 3: Integration and application of new knowledge in ways useful for development and science practice

The current project builds on a previous ACIAR project that ran from 2007 to 2010. Several research outcomes from that project are being further developed in the current project and some are being scaled out. A key learning from the previous project was that the dominant traditional crop, *transplanted* rice, is a risky proposition for smallholder farmers on the East India Plateau. The problem is caused by climate variability during the commencement of the monsoon (late May to early July) resulting in highly variable timing and duration of ponding. The resulting late transplanting leads to low crop yields and regular crop failure. More climate resilient crop options include aerobic rice (also called direct seeded rice, upland rice) where the crop seed is sown directly into non-ponded conditions, and also a range of other crop options including maize and vegetables. Consequently, increasing crop intensity (number of crops from the same field per year) and crop diversity (different crop species grown across the landscape and seasons) has become a central principle of the project, and a number of research innovations are focussed on communicating and researching this principle with farmers.

A year round crop planning tool has been developed to facilitate farmer learning about their land and water resources and assist farmers to plan a more complex cropping system. The tool consists of a matrix combining climate variability during the *kharif* (monsoon) season and residual soil water in the *rabi* (post-monsoon) season along the horizontal axis, with position in the landscape (uplands, medium uplands, medium lowlands, lowlands) along the vertical axis. Farmers populate the resulting matrix with crop options, choosing from a range of tested crops with known different water demands, to create a year-round, landscape-position, cropping plan. In 2013 this tool was scaled out to 700 farmers in the Purulia District by PRADAN. Later, as research becomes available, we plan to add sustainable utilisation of groundwater to the tool.

A visual representation of the impact of the project on crop intensity and diversity has been created using Google Maps. By recording crop history in individual fields in selected research villages and overlaying this data onto a single high resolution Google Maps image of the village, a visual record of change can be created. The resulting series of images provides a powerful spatial and temporal record of community achievement, effectively communicating development progress, providing motivation and incentive, and ongoing individual and community learning.

These two previous examples focus on bio-physical technical interventions, essentially a more knowledge intensive farming system that better utilises available land and water resources. Part of the success of this intervention is due to two favourable external drivers; the presence of largely unrecognised and underutilised natural resources, and strong market demand for vegetables translating into profitable on-farm enterprises. But we also believe a large part of the success has been due to the process of engagement, and we want to understand the essential features of this process so it can be scaled out effectively and efficiently. We believe that by involving farmers as participants in the research process they are experiencing success and this is leading to a sense of agency. For example, women used to regard themselves as labourers, but now see themselves as farmers. And in reality, many of our women farmers are acting as researchers and teachers to their fellow villagers. Regular (fortnightly) field walks around our research fields attract 30-40 villagers, and less regular impromptu field days can attract up to 200 farmers from neighboring villages. We are witnessing farmer-to-farmer learning and it appears to be very effective in promoting change in farming practice. By creating space for farmers to experience success we appear to have unlocked their latent capacity for innovation.

Research outcomes informing development practice and advancing science

The current project was conceived as an agricultural research project embedded in a rural development program. There is an intention to deliver results useful for both the practice of rural development and the science of agriculture. Emerging transdisciplinary research questions are also detailed.

Research results useful for the practice of rural development

Project research activity is concentrated on agricultural interventions, but importantly, these agricultural interventions are evaluated through the lens of rural development. More specifically, project focus is on the impact of agricultural interventions on rural livelihoods, including impacts on household income, food security, and the emancipation of women (Table 1). Each of these impacts is being monitored, some have been measured over several years, and others are based on anecdotal observations. In terms of the practice of rural development, two innovations are detailed below; first, the project has developed a process of farmer engagement based on participation in on-farm research; second we are developing a process for scaling out this engagement process.

Table 1: Project impacts across a range of development objectives

Objective	Prior to Project	After Project
Household income	Minimal cash income from on-farm activity.	Average annual household income increased by ₹10,400 over four years (2008-2011). Some households have earned ₹100,000 in one season from vegetables.
Food security	80% of households with only six months food security.	Nearly all households have 12 months food security. FS enhanced both from consumption of own production, and through purchases using higher income.
Nutrition security	Malnutrition severe and widespread, particularly women and children.	Nutrition intensive interventions include; pulses (Chickpea, Pigeon Pea, Black Gram, Mung Bean), oilseeds (Mustard), vegetables (Cow Pea, French Bean, Tomatoes, Cucumber, Gourds), forages for small ruminants (goats).
Distressed migration	Young adults, particularly males, forced to leave home seeking low-paid employment in towns and cities.	Distressed migration almost absent due to attractive on-farm enterprises.
Participation in local markets	Almost no participation in local markets to sell farm produce.	Regular participation in local markets. Some local youths employed as 'consolidators', collecting produce from individual farms to sell in markets.
Climate resilience	Traditional rice culture relies on transplanting. Climate variability results in late transplanting and failed crops.	Aerobic rice now established by manual direct seeding into non-flooded conditions. Using this method, rice crops can be sown on time with reliable crop yield even in dry years.
Empowering women	Tribal women see themselves as labourers, with low self-esteem, and little capacity for improving their lives.	Tribal women begin to see themselves first as farmers, then as researchers and trainers. 'Sense of agency' facilitated and women acting as entrepreneurs.

PRADAN's focus on deep community engagement (e.g. Women's Self Help Groups) combined with UWS's focus on participatory on-farm agricultural research has evolved into a process of engagement centered on farmer implemented agricultural research that provides deep learning experiences for the participating research farmers. The agricultural research activity provides the context for experiential learning leading to changed perceptions of self, land, and water. For example, women villagers now see themselves as farmers rather than labourers, uplands once regarded as least productive are now seen as the most profitable for vegetable production, residual soil water following rice harvest previously unrecognised is now seen as an opportunity to grow a second crop. Changed perceptions lead to changes in practice. Experience of success provided by participation in research provides confidence to innovate outside of the research activity. Farmers (along with development professionals and scientists) are active participants in all four stages (Plan – Do – Observe – Reflect) of an iterative action learning cycle.

Can this process of engagement based on farmer participation in research be scaled out? More fundamentally, what are the core attributes of the process that need to be incorporated? These questions are the subject of ongoing project research (see Section 4.3) but already we are seeing some elements influencing PRADAN's practice, and the Indian Government has recognised PRADAN's effectiveness by recently awarding them a support and coordination role in the National Rural Livelihood Mission. While it is too early to make any definitive statement on the potential for scaling this process out, what is clear is that progress depends on long term partnerships and trust, respect for smallholder farmers, and belief in their rights. Facilitating a sense of agency is a first and critical step towards a future of unknown potential, extending far beyond mere agricultural production, not wishing to diminish the importance of food production in a context where food insecurity and malnutrition are widespread and severe.

Research results useful for advancing science of agriculture

While a number of discrete agricultural research objectives are being investigated, most project research activity has interdisciplinary and often transdisciplinary dimensions. Discrete agricultural research objectives include; developing aerobic rice as an alternative to transplanted rice, introducing new vegetable species and management systems, improving goat nutrition by integrating available feed resources into year-round feeding plans, ameliorating soil conditions to improve water use and crop yield of *rabi* crops, developing guidelines for sustainable utilisation of groundwater. To illustrate the transdisciplinary research activity associated with a discrete research objective, the example of aerobic rice is discussed.

Aerobic rice (also described as direct seeded rice or upland rice) is a much more reliable system for growing rice in this environment. Especially in years with a late arrival of the monsoon, aerobic rice can still produce high grain yield whereas transplanted rice may not produce any yield at all. There are many technical challenges to making the transition from transplanted to aerobic rice. These include changed tillage practices (removal of the need for 'puddling', a process of compacting a layer of soil just below the surface to reduce drainage rates and encourage ponding of water needed for transplanting), identifying optimum seeding rates and plant densities, changed weed population dynamics and the need for different weed management strategies (usually but not necessarily including herbicides), changed availability of key nutrients like phosphorus requiring altered fertiliser application rates, largely unknown changes to pest and disease burdens, likely requirement for different rice genotypes compared to traditional genotypes (requiring evaluation of new rice varieties including early maturing varieties (90-100 days) for the changed environmental conditions), changed sowing and harvest times creating both challenges and opportunities, and related to this last point the opportunity for sowing a second crop following rice harvest. This is a significant list of research topics and more than enough to keep an agronomist busy for several seasons, but the transition to aerobic rice has other far-reaching implications from a livelihood perspective.

Making the transition from transplanted to aerobic rice is a move towards a more climate resilient agricultural system, it is a nutritionally sensitive agricultural intervention, and it frees women from menial labour. How is it that an apparently simple change in rice establishment method can have such far-reaching benefits? Traditional transplanted rice is very unreliable in this environment and avoiding the need to transplant by directly seeding the rice crop avoids this risk completely. Even in very late monsoon seasons there is enough soil moisture to establish a rice crop by direct seeding. Aerobic rice can be sown up to one month earlier than transplanted rice, resulting in the crop being harvested 2-4 weeks earlier, allowing a following *rabi* crop to be sown up to one month earlier (mid-October rather than mid-November) before surface soil moisture evaporates. This *rabi* crop can be a pulse (chickpea, field pea), an oilseed (mustard), or vegetables (tomato, eggplant, etc.), improving both home consumption of nutritionally intense food and increasing cash income that can be used to purchase nutritious food. Traditionally, hand transplanting of rice and hand weeding of transplanted rice is undertaken by women only. Aerobic rice frees women from this menial work, requiring no transplanting, and weeding utilises a manually pushed weeder that men are willing to operate. Overall, aerobic rice requires just one third of the labour of transplanted rice, freeing women for more creative pursuits.

Furthermore, through the planned participation of farmers in the research process, participating farmers not only develop confidence to change their traditional farming practice, they also become the most effective agents for communicating the new system to fellow farmers. By experiencing success in a very public research process, the self-esteem of research farmers and their status among peers has been enhanced leading to an enhanced sense of agency.

Emerging transdisciplinary research questions

Crop intensity has increased from one crop per year to two, three and even four crops per year from the same field. Crop diversity has increased from one crop (transplanted rice) to more than ten crop species (rice, mustard, chickpea, field pea, French Bean, Maize, Cowpea, Black Gram, Mungbean, tomato, eggplant, cucumber, gourds, etc.) grown by a single family over one year. Does increased crop diversity lead to increased diet diversity? The intuitive answer is yes, but there is very little evidence to support this conclusion (Anonymous, 2013). Crop diversity could increase diet diversity directly through consumption of farm-grown crops and/or indirectly via increased cash income used to purchase food. Current project thinking is to monitor diet diversity (e.g. Dietary Diversity Score, Food Consumption Score, Months of Adequate Household Food Provisioning, Household Hunger Scale) in a subsample of households currently included in project Monitoring and Evaluation. Diet monitoring would need to be completed by individuals (men, women, and children) within the household as it is traditional practice for women to deny themselves food during periods of food scarcity.

There is a debate in the development literature on the relative importance of developing the family farm and household economy versus development in the wider economy (Dorward et al., 2009). This project is focussed on interventions that sustainably intensify on-farm production and household income. There is anecdotal evidence that increased on-farm activity is generating off-farm employment and businesses. For example, some youths are acting as ‘consolidators’, collecting produce from individual farms and transporting produce to local markets. Similarly, there is some co-operative purchasing of crop inputs (fertilisers, seeds, etc.) by Self Help Groups. At the same time there are wider economy developments like better roads, health services, education, and more employment opportunities. There is a research opportunity to monitor the impact of on-farm intensification on local employment and business opportunities. Existing project Monitoring and Evaluation has been designed to separate the effects of on-farm and off-farm income on household economy. Integrative analysis of all these data should allow a better under-

standing of the relative importance of household economy and the wider economy on rural livelihoods.

What is our shared understanding of a 'sense of agency'? Is our agricultural research process providing experiences that enhance a sense of agency among participating women farmers? What does this mean to them? What are the salient features of the engagement process? Can this process be scaled out? These are some of the questions we hope to explore with farmers and development professionals as part of the conduct of the project. Witnessing project impacts on livelihoods in the villages it is apparent that significant changes are taking place, and that the trust established between villagers and PRADAN development professionals is central to this development. Critics point out the high cost of the engagement process and question if it can be scaled out. This focus on cost misses the value proposition. If we truly are developing a sense of agency, then villagers will be in a stronger position to determine their own futures, possess a greater capacity for innovation, and will be less dependent of government handouts. Understanding this complex process will be challenging, but the potential rewards justify the effort.

Reflection

Consistent with the conceptual model of transdisciplinary research (Lang et al., 2012), this AR4D project deliberately combined scientists and non-scientists in research activity with the intention of producing outcomes useful for both development and science practice. There is no doubt that project interventions are having positive outcomes for the livelihoods of participating farmers. There is also clear evidence that project research is leading to changes in the way development professionals engage with local communities, and that project research is influencing the selection of development issues, for example integrated cropping systems. The impact of the project on science practice is less clear, but there are significant implications, for example the involvement of farmers in data collection, the integration of data across several disciplines, and the emergence of new transdisciplinary research questions. More time is needed for a comprehensive evaluation.

A number of parallels between project research activity and the model of transdisciplinary research have been highlighted. These parallels cover all three phases of transdisciplinary research (problem framing and team building, implementation of research, integration and application of research). The greatest departure of the project from the conceptual model was in Phase 1, where the project team failed to explicitly recognise our research as transdisciplinary, leading to a lack of clarity in roles and responsibilities, especially relating to scientists. Greater attention to developing a shared understanding of conceptual and methodological frameworks, and boundary issues, would lead to clearer expectations in all project members. In the current project we will revisit this issue with the aim of developing this shared understanding. Progress in developing a shared understanding (Phase 1) will have benefits for integrative research (Phase 2) and the application of research for development or science practice (Phase 3).

What is the added value of a transdisciplinary research process in the context of agricultural research for development? Or as Jahn (2013) puts it;

> "…the quality of the 'transdisciplinary added value' of a given set of research results, the value won, that is, for both societal and scientific praxis, as each follows its own epistemic path."

In the current project, science practice was framed within development perspectives thereby improving research relevance and impact, and development practice was informed by science thereby adding rigour and providing greater confidence in selected development strategies. These broad domains of 'added value' have significant implications for the conduct of project research and overall project impact. Another more subtle 'added value' lies in the domain of cognitive

development in project team members. For farmers we might refer to their 'sense of agency', and for scientists their 'epistemic development', but for all stakeholders, participation in project research is challenging the way we perceive the world around us, and our role in it. As we grapple with the challenge of sustainability, the opportunity for cognitive development inherent in transdisciplinary research promises significant progress and warrants greater attention.

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