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SPECIAL ISSUE: ACIAR AT WORK: INTERDISCIPLINARY RESEARCH INTO SMALLHOLDER FARMING SYSTEMS

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SPECIAL ISSUE

ACIAR at Work: Interdisciplinary Research into Smallholder Farming Systems.

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Eds: J M Dixon and S G Coffey

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MANAGING EDITOR

Shaun Coffey

Advances in agriculture depend on innovation underpinned by science. These advances lead to improved productivity as well is improved outcomes of the natural resource base, animal welfare, plant and animal quarantine and health, and food safety. They also lead to the development of adaptive management practices that ensure increased resilience for the agricultural sector in response to system challenges such the increased climate variability evident in the present widespread drought conditions across the country. Australia has an enviable record of achievement in agricultural research and development, and the Institute is a strong advocate of the need for science to continue to underpin the performance of agriculture.

In this Special Issue of the Journal we feature the work of an important part of Australia's agriculture and innovation system – the Australian Centre for International Agricultural Research. The impacts of the bilateral research that ACIAR conducts as part of Australia's overseas aid initiatives is just as important within Australia as it is to the many countries and systems in which we collaborate and this is recognised by the many Australian institutions who readily partner with ACIAR to deliver research and development activities internationally. They recognise both the benefit that can be delivered directly from the research, and, more systemically, through the developments of linkages and maintenance of research capability to continue our efforts at home.

A 2013 task force report prepared for The Crawford Fund – "Doing Well by Doing Good[1]" provides many examples of how international agricultural research benefits Australia as well as developing countries. These include:

- Biosecurity gains from understanding mite pests of honeybees (Australian partner was CSIRO).
- Access to the Japanese mango market through post-harvest treatment of fruit fly (Queensland government)
- development of the sandalwood industry in Indonesia and the Ord River (WA government) and
- incorporation of ICRISAT germplasm in the Australian sorghum breeding system (various agencies).

The papers published here report research into farming systems, and the contributions that Australian agricultural science is making to improve the productivity, sustainability and resilience of those systems. Most of this work is or has moved to transdisciplinary approaches that put farmers and land managers at the centre of the research efforts – an approach that is increasingly important within Australia's farmland food production system.

I thank ACIAR for agreeing to support the preparation of papers for the Special Issue that brings together, for perhaps the first time, a series of papers that fully reflects the scope of the ACIAR supported research in this field. I thank also the many authors who readily agreed to contribute, and to the referees who have generously given of their time. The effort proved to be larger than I had initially envisaged, and I would like to record my appreciation of the efforts that have been put in by John Dixon, who has played an important role as the senior Co-Editor of the volume. His understanding of the field has proved invaluable and personally I have benefited from many long and deep discussions about farming systems research.

John is one of a long list of Australian agricultural scientists and Institute members who have contributed to international agricultural research – some notably like Derek Tribe, Jim McWilliam, Lloyd Evans and Tony Fisher have also contributed to the development of the many international institutions with which Australia now partners in ensuring a flow of information and technology to and from Australia. Many Australians have been leaders in international centres, and we continue to punch above our weight in the contribution that we make.

As we go to press, I can also report that the next issue will report on some of the history of the contribution made by agricultural sceince to Australian agriculture. The papers for this coming issue are currently being considered by referees, and it is intended that Volume 31 (Number 2) will go to press by year end as my final contribution as managing editor.

Australia has long supported and benefited from international agricultural research. I trust that you will find a rich tapestry of information as you read your copy of the Journal. ACIAR is an institution of which we can all be proud.

[1]www.crawfordfund.org/focus/doing-well-by-doing-good/

FROM THE CHAIRMAN'S DESK

Turlough Guerin, Chairman, Ag Institute of Australia

Australia has long held a leading role in undertaking aid to developing nations with a focus on small rural landholdings and developing the industry and the community that it supports. Agriculture plays a vital role in economic growth and poverty reduction and key to the achievement of the Sustainable Development Goals, most especially global goal 2: Zero Hunger. Investing in agriculture is essential to improve food security for the majority of the world's poor, who rely directly on agriculture for subsistence, income and employment.

Australia advocates a comprehensive approach to agriculture and food security that targets the immediate needs of the poorest, while also strengthening the foundations of agricultural industries through improving agricultural productivity and opening new markets. Market-oriented economic, trade and agricultural policies, good governance and infrastructure underpin private-sector investment and agricultural innovation.

Australia has a strong focus on women's empowerment, given the important role women play in agriculture and food security. Australia also recognises the role agriculture plays in addressing the complex problem of improving nutrition and encourages nutrition-sensitive agricultural investments.

As well as contributing to food security, agriculture is a major source of prosperity in developing countries with large, poor rural populations. Meeting future food demand in a sustainable way will require major advances in productivity, market systems, natural resource management and governance. As the world's population grows, demand for food and agricultural products will continue to rise. These pressures compounded by climate change, will strain the world's resources in a way that could limit future prosperity and contribute to conflict and population displacement.

Australia supports a range of agricultural initiatives across its bilateral, regional and global programs. Australia also has highly valued technical and managerial capabilities in agricultural research which are being harnessed to improve agricultural productivity in developing countries. Through the Australian Centre for International Agricultural Research (ACIAR), the Government funds research to improve the knowledge and understanding of the challenges our partner countries face. The research also provides an evidence base to evaluate the impact of our work and improve the quality of the Australian aid program. In addition, DFAT and ACIAR work closely with research institutions such as the Consultative Group on International Agricultural Research (CGIAR), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and research organisations in developing countries to sustainably increase agricultural productivity and enhance rural livelihoods.

Many studies have shown that improving farming systems and food security in developing countries delivers enormous social, economic and environmental benefits for the community and reduces threats to wider political stability and global security. Australia is also a beneficiary of this collaborative research as is demonstrated in Crawford Fund studies.

ACIAR's partnerships and their achievements support Australia's national interests in many different ways. Agricultural research for development has proven to be highly effective to aid the goals of enhanced prosperity and reduced poverty in partner developing countries, and this contributes directly to regional peace and security .

Economic prosperity in partner developing countries also has significant spill over benefits for Australia: stronger economies in the region offer new trade, investment and business opportunities for Australia.

Australia provides immediate humanitarian food assistance delivered through agencies such as the World Food Programme (WFP) and the UN Food and Agriculture Organisation (FAO). Our overseas development assistance—including through the Australian Centre for International Agricultural Research (ACIAR)—helps improve agricultural productivity and reduce post-harvest losses. It is the ACIAR that is the focus of the current issue of our journal.

The papers in this issue reflect not only the depth of Australia's contribution to knowledge on the global scale; they also attest to the dedication and capability of Australia'research scientist and a large cohort of the Institute's membership. I trust you share my view that this volume is a rich and rewarding set of papers to read.

THE ROLE OF SYSTEMS RESEARCH IN ACIAR PARTNERSHIPS

This Special Issue of the Journal of Agricultural Science brings a very welcome focus onto smallholder farming systems in low- and middle-income countries, and the contributions that Australian agricultural science is making to improve the productivity, sustainability and resilience of those systems.

These contributions are actively supported by ACIAR – the Australian Centre for International Agricultural Research – established in 1982 by the Fraser government with a view to "encourage research for the purpose of identifying, or finding solutions to, agricultural problems of developing countries" (ACIAR Act 1982). From the outset, ACIAR developed a partnership model that encourages and supports Australian scientists to jointly develop and implement research projects and programs with their counterparts in partner countries, within the framework of funding agreements between the Australian Government (through ACIAR) and relevant partner government(s).

Almost 100 independent evaluations (to which Alford and de Meyer refer in this Special Issue) have shown that this international partnership model has consistently delivered research that has made a difference in the farming systems and livelihoods of countless smallholder farmers, fishers and forest growers in our region, and has delivered very high returns on Australian aid investments. Less well-recognised perhaps, are the benefits flowing back to Australian rural industries and the Australian rural innovation system. For example, Australian scientists are able to work on pest and disease problems through ACIAR-funded projects, well before they get to Australia. Australian researchers are often able to incorporate insights and innovations from their international experience into their work with Australian industry for mutual benefit. Several senior Australian research leaders have recounted to me that an ACIAR project early in their career was a formative experience and a catalytic moment in their career.

Well into our fourth decade, ACIAR is confident that our raison d'etre is as relevant today as it was in 1982 when ACIAR was established. The Australian rural innovation system has much to offer the countries of our region as they tackle the converging insecurities of food, water and energy, all of which are amplified by climate change. Equally, Australian science and Australian primary industries have much to gain by working on these shared challenges in partnership with our neighbouring countries. The ACIAR partnership model, complemented by strategic investment in multilateral collaborations like the CGIAR, is holding up very well.

But it is equally clear that the challenge is no longer just about how to grow more food. Our challenge now is to grow more and healthier food, more equitably distributed, using less land, less water, less fossil-fuel energy, and leaking fewer nutrients and greenhouse gases. The food system is now increasingly seen as a priority for research in both global public health debates (EAT-Lancet Commission[1]), and global climate change debates (recent IPCC report on Land sector[2]).

We still need good, tightly-focused research projects that may apply the insights and tools from a single discipline on a particular aspect of a farming system or agrifood system. But it is much easier to find that missing piece of a jigsaw puzzle if stakeholders understand the whole picture. Increasingly, our research with partners across our region is looking at the intersections and interactions between food, water, climate and energy, in the context of farming systems, ecosystems and value chains. This necessitates multi-, inter- and transdisciplinary perspectives, in generally larger research teams working on multifaceted projects of longer duration, ideally with strong engagement from industry and policy stakeholders from the outset. Such research is sometimes perceived as complicated and, from the outside at least, often a bit messy. For farmers and agrifood businesses, small and large, such messiness and reconciling often-conflicting objectives is their daily reality.

[1]*Willett W, Rockström J, Loken B, et al., (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet: 393: 447-492*

[2] *IPCC Special Report on Climate Change, Desertification, LandDegradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems (2019) https://www.ipcc.ch/report/srccl/*

> "encourage research for the purpose of identifying, or finding solutions to, agricultural problems of developing countries."

In Australia, as in our partner countries, we need to get much better at systems research. Such research is essential to generate more useful evidence to inform policy and industry responses to the intertwined 'wicked problems' of food security, water security and energy security while conserving natural resources and adapting to, and hopefully mitigating, climate change.

This Special Issue is very timely. It is great to have within a single volume, systems-based approaches to agricultural research for development ranging across cropping systems, agroforestry, natural resource management, economics, and methodological issues in different cultural and agro-ecological contexts. Editors John Dixon and Shaun Coffey and authors of the papers have done an excellent job, reflecting on early work and looking to the future in the Pacific, Asia and Africa – and the CGIAR. Australia has long been a leader in farming systems research, and it is fascinating to read about Bob McCown's early work in the first ACIAR research project linking Kenya and Katherine.

Obviously I am far from being a disinterested observer, but from our perspective, public investment in this type of research, in partnership with countries across our region, has been and continues to be a great investment for Australia. The skills, insights, networks and experience that Australian scientists build through ACIAR projects are increasingly relevant here in Australia. We need to build more and better capabilities in farming systems research, in Australia and overseas, if we are to have any hope of feeding the world better and sustainably.

I commend this Special Issue, and invite readers to comment on a very interesting set of papers. You can find much more information about ACIAR, our projects and our publications, including the excellent Impact Assessment series, at www.aciar.gov.au.

ANDREW CAMPBELL, FTSE
CEO Australian Centre for International Agricultural Research (ACIAR), Canberra

AUSTRALIAN CENTRE FOR INTERNATIONAL RESEARCH

The Australian Centre for International Agricultural Research (ACIAR) is the Australian Government's specialist agricultural research-for-development agency, within the Australian aid program. ACIAR was established by the Australian Centre for International Agricultural Research Act 1982 and is an agency of the Foreign Affairs and Trade portfolio.

The mission of ACIAR is to achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia, through international agricultural research partnerships. We broker, facilitate, invest in and manage strategic partnerships in agricultural research-for-development.

Australia's world-leading agricultural innovation system is a strategic national capability that ACIAR is able to mobilise in international research partnerships. Australia's security and economic interests remain inter-linked with the countries of the regions in which ACIAR operates: Pacific, East and South-East Asia, South Asia and eastern and southern Africa. Investment by the Australian Government in agricultural development, through ACIAR, supports regional processes for promoting peace and economic growth.

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Rice-wheat system woman farmer, Nepal

AN AUSTRALIAN CONTRIBUTION TO FARMING SYSTEMS RESEARCH IN INTERNATIONAL PARTNERSHIPS

Agricultural Science Special Issue: ACIAR at Work: Interdisciplinary Research into Smallholder Farming Systems. Combined Volumes 30(2) and 31(1): 2019. Eds: J M Dixon and S G Coffey

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BIOGRAPHICAL NOTES

JOHN DIXON
Adjunct Professor UQ, Visiting Fellow ANU

John Dixon FTSE has worked with UNE, FAO, CIMMYT, ACIAR, ANU and University of Queensland with systems approaches for research, rural development, agricultural and environmental policy and capacity building over 40 years in all developing regions of the world. Notable applications of systems R&D include: global maize and wheat farming systems; conservation agriculture based sustainable intensification; environmental and agricultural management; farmer-extension-research-business innovation systems; national and regional data and knowledge systems; and investment targeting, research prioritization, impact assessment and policy engagement. He is an ATSE Fellow, Global Evergreen Alliance Fellow, UNE Distinguished Alumnus, USAID Sustainable Intensification Innovation Lab Board member, and an M S Swaminathan laureate.

BRIAN KEATING
Honorary Fellow, CSIRO

Brian Keating' career has focused on the productivity and sustainability of agricultural systems in Australia and sub-Saharan Africa. He was a pioneer in the development and application of simulation models in farming systems research in the 1980's and 90's. Senor leadership roles in CSIRO have included: Chief of CSIRO Sustainable Ecosystems (2004-2007), Director of Sustainable Agriculture Flagship (2008-2013) and the member of the CSIRO Executive responsible for Agriculture, Food and Health (2014-2015). He is currently an Honorary Fellow at CSIRO Agriculture and Food and Chair of the Independent Steering Committee of the CGIAR Program on Climate Change, Agriculture and Food Security (CCAFS).

PETER CARBERRY
Director General
ICRISAT

Peter Carberry FAIAST, FTSE is the Director General of ICRISAT. He previously served as ICRISAT Deputy Director General and the Director of the CGIAR Research Program on Grain Legumes & Dryland Cereals. Prior to joining ICRISAT in 2015, he was a Chief Research Scientist in CSIRO, Australia. Dr Carberry's research expertise is in crop physiology, in the development and application of farming systems simulation models and in use of information systems in agriculture. He has been a key developer of the APSIM modelling framework.

ABSTRACT

This review of an Australian contribution to farming systems research (FSR) honours Dr R L (Bob) McCown (1937-2017) and his innovations in and advocacy of FSR practice in Australia, Africa and globally. Australian contributions to international FSR development and practice are widely recognized, notably in the CGIAR Centers, World Bank and ACIAR-supported international research partnerships. There has been a resurgence of interest in farming system approaches with the growing challenges of complex, uncertain, 'wicked' problems. McCown's leadership and insights helped shape a particular "Australian-style" of FSR and influenced international FSR practice over four decades, particularly the incorporation of simulation modelling in framing researcher connections with farmers' decision-making. The paper concludes with some priorities for refinement of FSR methods for international agricultural research in the years ahead.

DEDICATION

"Crops come and go over time, finding the soil in a particular state and leaving it in another" (McCown et al. 1996). With these deceptively simple words, McCown and his colleagues launched a new era of farming systems analytical capability that, in hindsight, can be seen to have reinvigorated FSR methods globally over the last 25 years. Over time, not only crops would "come and go", but also seasons, pastures, livestock, trees, farm managers and markets, all shaping the short and long-term performance of the farming system. The simplicity of this concept shapes the philosophical approach of agronomists and other agricultural scientists seeking to influence farming system productivity and sustainability.

BACKGROUND

Australia is known globally for success in dryland agriculture, but the reasons behind the success are less well understood. Sometimes the productivity or disease resistance of improved breeds, pasture species or crop cultivars have been extolled, but the complementary farming systems research (FSR) process – of testing, fine-tuning and evaluating the combinations of improved germplasm, crop/livestock/pasture management practices and, increasingly, markets and policy conditions – has been frequently overlooked. The essential role of FSR of increasing overall research productivity, through complementing disciplinary and commodity research, requires a shift of focus to farmer-centric investigation. Research targeted to homogeneous farming system domains, combining participatory field experimentation with simulation modelling and implemented by small multi-disciplinary teams with adequate budgetary and stakeholder support has been a hallmark of FSR. Cooperating with farmers while interacting with disciplinary and commodity researchers, landscape managers, agribusiness and policy makers are critical attributes.

During six decades of FSR application (from 1960) there has been a progressive broadening of agricultural research and development agendas. Farming has evolved, differentiated and responded to new opportunities and risks associated with natural resources, climate, technologies, markets and policies. The responsiveness of the agricultural sector as a whole to such changing circumstances depends ultimately on the management decisions of millions of farmers as well as service providers and value chain entrepreneurs who connect consumers to farmers. As circumstances changed, FSR approaches and practices were enriched in order to contribute to the broader agendas such as food and nutrition security, poverty reduction, equity and sustainability.

A number of factors can be seen to have shaped a particular "Australian-style" of FSR. These include:

- Australia's highly variable climate and soil constraints, and unsubsidized markets (managing risks is essential);
- an R&D funding policy regime that connects research activity to farmer circumstances (via levy-based farmer contributions);
- strong connections between domestic agricultural research and international research partnerships (many FSR innovations in Australia can be traced back to ACIAR-supported research in Africa, Asia or the Pacific); and
- a tradition of individuals who have shown leadership at home and abroad in farming systems approaches.

While we are focusing on McCown's contributions in this paper, he would be the first to acknowledge the wider international contribution of many Australian scientists (some of whom are mentioned herein), including those he mentored, as well as how much he learnt from colleagues including agricultural economists. In tracing the development of FSR, the importance of the ACIAR-supported international linkages between Australian research teams and developing country teams and their problems cannot be over-emphasised.

HIGHLIGHTS OF CONTRIBUTIONS BY BOB MCCOWN TO FSR METHODS

As one of many definitions of farming systems, for the purpose of this paper a farming system can be defined as a "Production System of crops, pastures, animals, soil and climate together with a range of bio-physical inputs and outputs and a Management System made up of people, values, goals, knowledge, resources and monitoring" (Keating and McCown 2001). With such active experimentation and innovation with FSR methods over the past six decades, the FSR concept has been enriched and the approach been tailored for specific purposes. There are also a number of other agricultural research approaches with similar conceptual underpinnings to FSR which were developed in parallel, often with substantial cross-fertilization with FSR. These include Rapid Rural Appraisal (RRA), Participatory Rural Appraisal (PRA), Agroecosystems Analysis and the Sustainable Livelihoods Approach (Dixon et al. 2001).

McCown's journey of discovery in farming systems approaches was a journey of pushing back the boundaries in the pursuit of improving the impact that professional agricultural science (the world of theory) can have on real-world farming (the world of practice). Through his long and rich career, McCown's thinking was often ahead of the debates of the mainstream of the systems and FSR community. Repeatedly, just as his team was making effective progress, he would move onto the next challenge and frequently draw his team into unfamiliar territory, disciplines and themes. He advocated systems approaches in general and FSR in particular to the biophysical scientists on his team in the late 1970s. As FSR gained traction in the field during the 1980s, he proposed the addition of crop modelling to the FSR suite of methods; and as crop modelling was 'coming of age', his vision of FSR had shifted towards the linkage of modelling with richer understandings of farmer behaviour and decision making.

The foundations – FSR in the 70's and 80's reinvented for the 90's and beyond.

The foundations for FSR had been laid by a wave of experimentation with participatory systems diagnosis and on-farm research in Central America and Africa during the 1960's and 1970's. Figure 1 represents the classic FSR thinking of the late 1970's and early 1980's (see Dillon 1976, Dixon 1978, Collinson 1982). The vision was to better connect "On Station" technical research with smallholders' needs through "On Farm" adaptive research. FSR emerged in response to a view that agricultural research was losing its relevance to the needs of "real world" farmers, either because (a) researchers misunderstood farmers' needs or (b) farmers could not grasp the relevance of the research results. FSR programs quickly became major components in many international research programs in the CGIAR Centers (Dillon et al. 1978) and most major development donor programs including USAID. Significant effort went into methodological guidelines and training programs.

Figure 1. The classic FSR framework (Collinson 1982).

Following an ACIAR regional consultation in East Africa in the early 1980s (ACIAR 1984), McCown, Keating and others pioneered FSR methods in the rainfed highland, maize-mixed, farming system in Kenya – on the very first ACIAR project in Africa. This Kenyan research unfolded in parallel with research directed at the development of innovative legume ley farming systems in northern Australia (Carberry et al. 1996).

The decade of the 1980s was a period of intense innovation in FSR methods, fostered by generous funding and applications in a growing range of biophysical and socio/institutional environments, unconstrained by the straight jacket of 'standard' methods. To explore the role of FSR in international research, ACIAR convened an expert workshop in Australia (Remenyi 1985) which included McCown and many other fathers of FSR. In the ensuing decades many ACIAR research projects embodied elements of FSR such as multidisciplinary research teams, participatory diagnoses and technology evaluations, on-farm research trials with significant farmer engagement and crop, feed and whole farm modelling.

Bob McCown and Roger Jones led the Kenya maize-mixed farming systems project and the team quickly realized that the seasonal rainfall variability and the complexity of crop-soil-management-climate interactions were such that even an 8-year research project would not be able to unravel the risk dimensions of input use and farm management. Various research approaches including 'response farming' were tested on projects in East Africa (McCown et al. 1991), but none tackled adequately the full complexity of crop-soil-management-climate interactions. Hence the standard 1970's FSR approach emphasising participatory diagnosis and on-farm trials was modified to include a component of crop simulation modelling to complement the on-farm adaptive research (Figure 2). The term "operational research" in Figure 2 replaces "On Station Technical Research" from the Collinson "figure-8 diagram" in Figure 1. This approach aligned with the vision of another notable Australian agricultural scientist of the era (Henry Nix) who saw a role for models, particularly crop and soil models, to augment agronomy field trials.

Figure 2. The augmented farming systems research framework (McCown et al. 1994).

The ACIAR-funded FSR program in the dryland mixed-maize farming system in Kenya during the 1980's pioneered simulation analysis of on-station and on-farm trial results. Contrary to the agricultural development thinking at the time, this FSR effort in Kenya provided strong evidence and advocacy for low doses of inorganic fertilizer in smallholder farming systems (McCown et al. 1992). The crop modelling, validated on specific sites and seasons, enabled the wider interpretation of experimental results over different climatic and site environments (Keating et al. 1991). This particular role for system simulation is critical in agricultural research to the present day (Keating and Thorburn 2018).

Re-inventing farming systems simulation – the APSIM story

McCown was interested in modelling for practical ends. His early work in northern Australia picked up the water balance tools emerging from CSIRO's Land Assessment Team and developed tools for assessing pasture and livestock productivity in the face of high seasonal rainfall variability (McCown 1973). His Australian mentors and colleagues at the time – including Ralph Slatyer, Henry Nix, John McAlpine and Gail Keig – were early pioneers in plant-soil-climate modelling.

When a maize model was needed for the ACIAR-supported research in Kenya and northern Australia (Katherine) in 1985, McCown looked to Joe Ritchie's group in Texas and deployed an early version of CERES Maize (Jones et al. 1986). In fact, two of the co-authors on this paper were recruited and deployed the maize model, Keating in Kenya and Carberry in Australia. New "systems aspects" were patched-on CERES Maize to tackle issues identified by FSR, such as intercropping, weeds, thinning, dynamic planting in response to weather, crop sequence effects, seedling establishment, mulch effects and crop death due to extreme stress over the 1985-1990 period in Kenya and Katherine (Carberry et al. 1989).

By 1990 the potential utility of a comprehensive systems model was clear but the spaghetti-code and inflexible software architecture of the adapted CERES models was obviously not a stable platform. McCown led the conceptualisation of a fresh modelling platform – one that had a farming systems design philosophy at its core (reflecting the quote at the outset of this paper). AUSIM (McCown and Williams 1989) and soon after APSIM (McCown et al 1996, Keating et al. 2003, Holzworth et al. 2014) was the results of this effort. Almost 30 years after the need and opportunity was identified in 1990, APSIM is now one of the most widely used systems models globally (Keating and Thorburn 2018).

After the initial wave of investment by many donors in FSR subsided during the 1990s, it could be argued that the Australian multi-disciplinary, results-oriented experience in agricultural research underpinned continued investment by ACIAR in inter-disciplinary systems-oriented research. During the 1990s there were a series of modelling projects in Africa tackling risk management, fertilizer recommendations and climate variability supported by ACIAR, AusAID and IDRC. ACIAR support included significant contributions to the improvement of crop and crop-livestock farming systems analysis modelling tools such as APSIM and a related bio-economic tool for crop-livestock systems at a farm household level (IAT; Lisson et al. 2011). These modelling tools supported an increasing number of international projects especially as the agricultural development agenda broadened to include natural resource management, soil health and farming systems risk, resilience and adaptation to climate variability.

Re-inventing decision support for farming - FARMSCAPE

In the early 1990's, just as the systems models were gaining significant capability and application in Australian agronomy, McCown began to question the traditional view of computer-based decision support systems in agriculture (McCown et al. 1994, McCown 2002a,b). He realised that operations research and agricultural economics gave insight into researcher-driven attempts to deploy their analytical tools to real-world decision making. However, the most significant outcome was not the formal knowledge, tools or capacity that could be used to inform farmers about what "best practice would or should be", but instead the use of "the science to facilitate discovery learning about situated farming practice" (McCown et al. 2012).

The FARMSCAPE experience led to a broader view of farming systems research and related constructs as illustrated by Figure 3 (from McCown 2001). The scheme explores the landscape of agricultural knowledge production across domains (from local to general) and practice paradigms (from technical to social). While this scheme emphasises contrasts in knowledge production, McCown and colleagues recognised cross-connections across this agricultural knowledge production landscape. Arguably, well-managed research systems seek synergies across different types of research, for example, between on-farm FSR and station/lab-based experimentation.

Providing deep understanding on the role of science outputs in farm decision-making.

A real contribution of McCown and his team was the documentation of learning and evolution in systems thinking over a long career (see http://bob-mccown.com/). In a milestone paper, McCown et al. (2009) explained an evolution in systems thinking – commencing with FSR in the field, drawing on the FARMSCAPE experience within Australian agriculture, interpreted through a broad global systems literature and explained using conceptual frameworks. This journey culminated in the publication of his seminal paper, the title of which articulates a simple but critical conclusion: "Farmers use intuition to reinvent analytic decision support for managing seasonal climatic variability" (McCown et al. 2012). In a related milestone paper, McCown (2012) presents a cognitive systems framework describing human decision-making based on his reading of the literature from well outside the domains of agriculture or hard systems sciences. This framework focuses on farmers' intuitive management of seasonal climatic variability, recognizing that family farming is a livelihood pursuit where farm decisions are intertwined with farmer lives and lifestyles. Thus, family farming is managed in a different way to businesses, governed by policies and rules set and evaluated by Boards and shareholders.

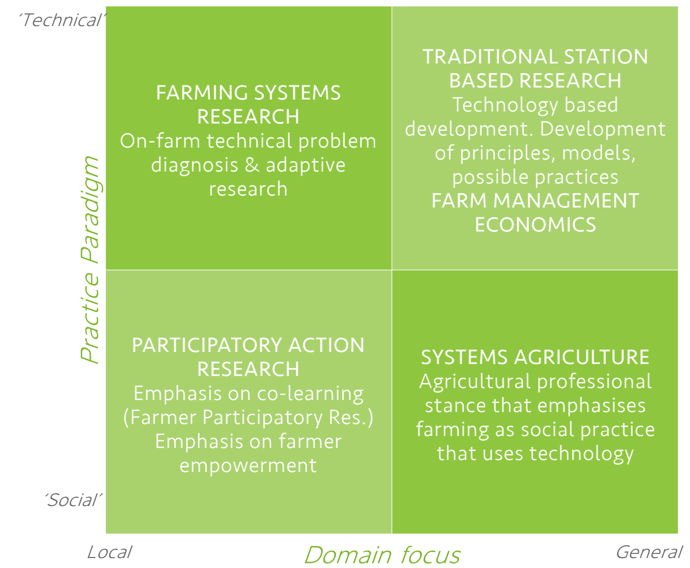

Figure 3: Agricultural knowledge production interfaces (McCown 2001)

Within this cognitive framework, Figure 4 simply represents the interplay between decision-making informed by both intuition and analysis, both of which contribute to situation awareness and forming of expectations as input into an individual's planning and decision making. McCown et al. (2012) argue that it is when farmers seek to turn to analysis that the opportunity arises for decision support informed by science. However, this insight appears largely absent in the enthusiastic rush towards SMS technology for advisory and market information services and smartphone based decision support tools promoted by both public and private sector stakeholders and investors.

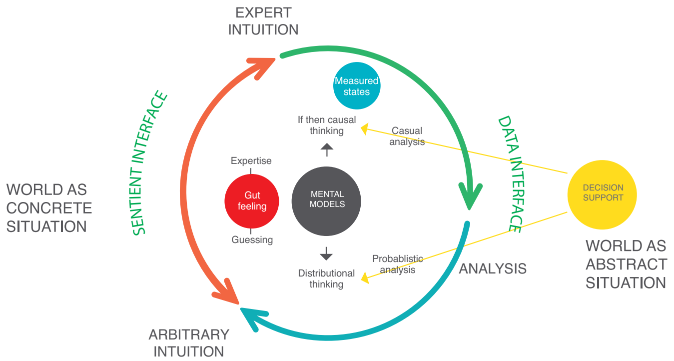

Figure 4: Judgement as a continuum from intuition to analysis (simplified from Figure 2 in McCown et al. 2012).

Legacy research initiatives

Many of McCown's insights during his long and productive career were reflected in international and Australian agricultural research initiatives (Carberry 2005, Whitbread et al. 2010, Connor et al. 2015). Twomlow et al. (2010) identify systems modelling as a source for the recommended practice of small doses of inorganic fertiliser in sub-Saharan Africa. In their review of impacts from using systems models in Australian-led international projects, Connor et al. (2015) identify real impacts from using simulation models in FSR. Dalgliesh et al. (2009) and Hochman et al. (2009) document the impacts in Australia of McCown's FSR team on farmers' use of enhanced soil monitoring and on the application of decision support systems.

During the current decade, participatory systems thinking continued to resonate with many ACIAR-supported research partnerships in soils, water management, forestry, livestock and cropping, including several systems-based sustainable intensification research initiatives. For example, in Africa the Sustainable Intensification of Maize and Legume Cropping Systems for improved Food Security in East and Southern Africa Program (SIMLESA) deployed FSR principles in research on conservation agriculture based sustainable intensification in eight countries. The Program improved food and nutrition security and increased household income, including 26-137% extra maize net income, of an estimated 484,000 farm households -- and reduced soil erosion by an estimated 34-65% (SIMLESA 2019). Research activities included participatory diagnosis, household survey, innovation platforms, on-farm research and demonstrations in 58 research hubs in 5 countries. The research results fed into pilot scaling activities, spillover management and policy dialogues. SIMLESA also contributed to another legacy, viz, the development of APSIM's whole farm model (APSFarm; de Voil et al. 2009, Rodriguez et al. 2011). APSFarm includes flexible crop rotations, allocation of land, labour and cash and estimation of profits, risks and trade-offs at the whole farm level, as well as environmental outcomes. The APSFarm model was applied to estimate risk profiles of technologies and trade-offs in the use of crop residues for 'mulching' compared with 'munching' as cattle fodder (Rodriguez et al. 2017). The innovation platforms, with their focus on learning, adaptation and decision making, facilitated farmer-to-farmer exchanges and co-learning across farmer, extension, research and business interfaces.

In South Asia, the Sustainable and Resilient Farming Systems Intensification project (SRFSI) also applied FSR principles on participatory on-farm research trials conservation agriculture based sustainable intensification in eight districts of Bangladesh, India and Nepal. The project simulated farming systems intensification under various climate scenarios and contributed to a major review of APSIM applications in South Asia (Gaydon et al. 2017). FSR approaches underpinned the establishment of innovation hubs and the convergence of pilot scaling initiatives of the project with major development programs of the Governments. The SRFSI project research demonstrated resilient intensified farming systems with improved water use efficiency, returns to family labour and food and nutrition security. More than 40,000 smallholders, of whom about 25% were headed by women, had benefited from initial scaling activities (Tiwari pers comm.).

REFLECTIONS ON WAYS FORWARD: IMPLICATIONS FOR FSR

Key biophysical and socioeconomic drivers of agricultural development will ensure continuing evolution of farming systems over the coming decade. Global demand for food and other agricultural produce and services is growing and consumer preferences are changing rapidly. Consequently, farmers and value chain actors face the challenges of simultaneously expanding and diversifying food supply, in the context of growing resource scarcity and climate variability and uncertain policy and trade regimes. Greater investment in agricultural research capacity, for commodity investigations, FSR and value chain analyses, is needed to tackle the complexity and uncertainty inherent in sustainable agricultural intensification and diversification.

> "A further strategic challenge for the FSR community is nudging senior research leaders and policy makers towards greater use of inter-disciplinary systems approaches in general and FSR in particular."

The role and contributions of FSR would benefit from improved positioning, capacity and research methods. The emerging context includes broader stakeholder narratives (from smallholder communities to Sustainable Development Goals), intense uncertainty (especially from climate change and technological developments) and complex institutions (related to common property resources, value chains, markets and policy environments). These aspects imply a potential broadening of farming systems analyses to include: consumption, nutrition and health; ecosystem services, including carbon sequestration; and local institutions including marketing (foreshadowed by Fleming and Hardaker (1993)). Consequently, the ratio of variables to parameters will rise, and FSR will make increasing use of multi-variate non-parametric analytical methods and simulation modelling. There will also be progressive growth in the importance of socioeconomic, cultural and institutional aspects of FSR, with implications for team expertise, experimental designs, inter-disciplinary analytical methods, scaling domains and policy engagement.

Advances in sensors, big data, computational power and artificial intelligence will revolutionize modelling and decision support tools. The electronic capture of household survey and trial data will not only enable immediate cleaning and storage, but also faster analysis and reporting. Multi-enterprise farming systems models such as APSFarm, incorporating trees, livestock, off-farm income and household nutrition, will increasingly integrate real-time data streams from sensors of physical, biological and economic conditions on farms and in markets. In parallel, the science content and computational efficiency of systems models will increase (Holzworth et al. 2018). One can envisage a time when "model-data fusion" approaches, as in modern weather forecasting, might be widely deployed in field and farm household analyses. Naturally, there is a high priority for effective interfaces between science, i.e., FSR modelling and decision support tools, and people, i.e., farm women and men.

Farmer preferences, behaviour, decision-making and operational management will become integral aspects of FSR diagnosis, testing and evaluation and will require a wider range of research methods. Best practice participatory diagnoses should identify farm women and men's priorities and risk preferences and priorities, and methods for decision making under risk and uncertainty should be fully integrated into farming systems models such as APSFarm, especially in relation to climate and market variability. The methods for risky decision making developed by the Australian FSR group at the University of New England were adapted by CGIAR Centers, most recently in an agri-food systems context. Ongoing ACIAR research in South Asia is investigating farm women's and men's decision making about the adoption and adaptation of knowledge intensive innovations such as conservation agriculture. Thus, the foundations are being laid for the further development of practical research tools for farmer (and business) decision making which could substantially enrich FSR.

Linking farm household and community knowledge (derived from FSR) and learning systems to broader watershed, landscape and national contexts is another methodological challenge for FSR. Focus groups, stakeholder consultation, role playing and negotiation techniques could facilitate policy dialogues. Better approaches to syntheses of existing knowledge for each stakeholder group would be valuable as is the recognition of farming system domains and representative farm-household types. The FAO-World Bank global farming system framework based on resource, production and livelihood patterns and development needs (Dixon et al. 2001) is an effective approach to improved targeting of FSR and strategic development investments – and was adopted in 2015 by the FARA Science Agenda for Agriculture in Africa. The characterization of the diversity of household types within each farming system zone also facilitates targeting (Wilkus et al. 2019). The distinction of Davis et al. (1987) between ‘recommendation’ domains for national adaptive/applied research and extension, and ‘research domains’ for strategic research and the management of international spill-overs, will still be relevant. Such a farming systems framework would increase the efficiency of targeting, synthesis and spillover of farming system-specific knowledge across countries and continents.

A further strategic challenge for the FSR community is nudging senior research leaders and policy makers towards greater use of inter-disciplinary systems approaches in general and FSR in particular. Three major opportunities could be of particular importance. Increased agricultural research intensity would fund commodity research while enabling expanded FSR capacity and activities. Rigorous methods are needed to link farming systems knowledge with the identification of impact pathways for new innovations. In a similar vein, better farming systems knowledge will underpin strategies for targeted scaling of agricultural innovations to farming system domains and household types. Visionary leadership and organizational change could modernise agricultural Ministries and Departments and foster systems research and FSR, for example by cross-cutting multi-sectoral coordination platforms, working groups and multi-disciplinary projects. There is greater scientific recognition of interdisciplinary research, and greater acceptance by academic journals. Active encouragement and participation of disciplinary researchers in FSR would contribute to its institutionalization.

One of the fundamental constraints to wider application of FSR is the critical shortage of agricultural scientists, including social scientists, with advanced formal training in inter-disciplinary systems research and modern tools of farming systems analysis. There have been a few notable agroecosystem-oriented agricultural undergraduate courses (e.g., UNE and Hawkesbury Agricultural College in Australia) and some multi-disciplinary post-graduate programs oriented to international research partnerships (e.g., James Cook University). Perhaps the greatest contribution to inter-disciplinary systems capacity has been made by short-course training in agriculture, environment and sustainable development, often in response to the growing prevalence of complex uncertain ‘wicked’ problems. In practice, the vast majority of FSR professionals learn “on the job” (sometimes inefficiently, but in the process often contribute to innovation in FSR methods). In this context, investments in modern FSR training would generate high pay-offs. While widespread tertiary education in systems analysis would be ideal, the establishment of mentoring platforms to support FSR scientists and development professionals would be feasible and effective, especially for those working with complex issues of smallholder sustainable development.

As exciting as these prospective advances in FSR might be, one lesson we take forward from the McCown era is that research-centric capabilities will have limited impact in the real-world without functional methods for effective interactions with the cognitive and value dimensions of decision making by farmers and other change agents – value chain actors, research leaders and policy makers. We are optimistic that practical methods for making effective use of the growing power of sensors, simulation and artificial intelligence, taking into account the recent breakthroughs in behavioural and decision-making science, will be developed for FSR, as well as networks of users - farm women and men, service providers, agribusiness and policy makers.


Cattle feeding on maize stover near farm homestead, Zimbabwe

“ Perhaps the greatest contribution to inter-disciplinary systems capacity has been made by short-course training in agriculture, environment and sustainable development, often in response to the growing prevalence of complex uncertain ‘wicked’ problems.”

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Woman farmer with forage legume rotated with maize, Ethiopia

Tony Bartlett with Rwandan champion farmer Mrs Mukarugwiza Clemence in her Utis-tree tomatoe agroforestry system located near the Karago Rural Resource Centre near Gishwati

FOSTERING A SYSTEMS-BASED AGROFORESTRY RESEARCH FOR DEVELOPMENT

Agricultural Science Special Issue: ACIAR at Work: Interdisciplinary Research into Smallholder Farming Systems. Combined Volumes 30(2) and 31(1): 2019. Eds: J Dixon and S G Coffey

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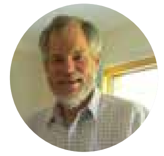
ABSTRACT

A diverse range of agroforestry practices are evident within farming systems in developing countries, but further research is needed to enhance their productivity and profitability and to facilitate participatory design and dissemination of locally appropriate practices that can be widely adopted. Because of their complexity, including the number of options, the interactions between the tree and non-tree components and the fact that many tree products need to be traded in commercial markets, best results from research interventions are likely to be achieved through a systems approach. This article describes the strategic components of the Australian Centre for International Agriculture's (ACIAR) approach for its systems-based agroforestry research and illustrates some key aspects with examples from ACIAR projects.

These include: understanding the impact pathway; having effective processes related to design, review and adaptation of projects; identifying locally-appropriate agroforestry innovations; having mechanisms to engage and empower project stakeholders; understanding value chains and facilitating value-adding of agroforestry products; and effective engagement of policy and private sector stakeholders.

BIOGRAPHICAL NOTES



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INTRODUCTION

Agroforestry combines the consideration of woody perennials, herbaceous plants, livestock and people, and their interactions with one another in farming and forest systems (Sinclair, 1999). Agroforestry practices, rather than systems, are also used as the unit of an ecologically-based classification that is rooted in the role of trees in agricultural landscapes (Atangana et al., 2014). There is an almost infinite number of possible agroforestry practices, involving combinations of different trees, crops, non-timber forest products and livestock components. Agroforestry has been practiced by farmers in developing countries for centuries, primarily to support their subsistence, but increasingly to provide important sources of income. Agroforestry, as it is practiced, is very rarely a whole farm or forest system, but rather more commonly involves trees being used in various productive niches within a farm and within farming landscapes (Sinclair, 1999). In this paper, the term agroforestry will include both traditional agroforestry, where trees are grown in conjunction with crop and livestock management, and smallholder woodlots where the tree component is on land dedicated to tree growing, but still part of the livelihood system.

Some traditional agroforestry research has involved controlled experiments on research stations, without incorporating the important but challenging dimensions of farmer behaviour, while other research has followed the farming systems approach with active participation of the intended beneficiaries. In this paper, the term systems-based agroforestry research refers to research that investigates interactions within and between the biophysical, social and economic components of agroforestry practices as well as the value chains into which the products are traded. This is therefore a broader conceptual approach to Farming Systems Research (Sands, 1986), which incorporates more recent understanding of the importance of researching mechanisms to strengthen farmer collaboration, for example through Innovation Platforms (Schut et al., 2016), and extending the approach further to include research on developing micro-enterprises and value-added processing of agroforestry products (Cunningham et al., 2017).

While agroforestry systems and agroforestry practices have been categorised (Nair, 1985, Sinclair, 1999), the application of agroforestry is immensely variable reflecting many different contexts including: geography, site factors, occurrence of tree species, tenure and size of landholdings, access to germplasm, existing knowledge and practices, access to markets and prevailing policies and regulations. Likewise, the livelihood benefits from trees in farming systems varies significantly but ACIAR-funded research has shown that in Indonesia, teak-based agroforestry systems contribute 12-15 percent of household income (Roshetko et al., 2013), while in Nepal, adoption of market-focussed agroforestry systems increased household income by up to 48 percent (Pandit et al., 2018).

Agroforestry research has been ongoing over the past four decades, generally seeking to enhance local practices in ways that will increase the benefits they produce for farmers and the environment. Research approaches have included both narrow-focussed research on tree growing and wider systems-focused research, covering the whole farming system as well as the value chain for the agroforestry products. However, with a few exceptions, the researcher-designed agroforestry practices have not achieved widespread adoption and therefore the aggregate impacts from much of this research has been lower than expected.

Denning (2001) reports on work that identified ten factors that influence the adoption of agroforestry by farmers, including farmer-centred research, and highlights the importance of research organisations partnering with development organisations to increase adoption. Franzel et al. (2001) highlight that achieving effective adoption of agroforestry often requires building institutional capacity in the community for promoting and sustaining the adoption process. More recently, Coe et al. (2014) have advocated that, in order to achieve effective scaling up of agroforestry, there is a need for appropriate research design, within the scaling process, that enables co-learning amongst research, development and private sector actors. All of these aspects could be considered to be essential components for consideration in a systems approach towards agroforestry research.

Enhancing the use of trees and forests in rural development requires consideration of both social and biophysical sciences and long investment periods, due to time required for many tree products to become merchantable. Often good technical agroforestry innovations will not succeed without appropriate understanding of the social and policy factors that affect their adoption by farmers, who are often by necessity risk adverse. In addition, many farmers are continually adapting their farming systems, due to ongoing changes in economic, social and environmental circumstances. Hence to be effective, agroforestry research must be capable of accommodating such changes.

For 35 years, the Australian Centre for International Agricultural Research (ACIAR) has been brokering and investing in international research for development (R4D) in the agriculture, fisheries and forestry sectors, to enhance the knowledge, technologies and capacity required to achieve development objectives in partner countries (ACIAR, 2017). From its inception in the early 1980s, ACIAR has supported research on agroforestry and smallholder forestry. In the early years, ACIAR agroforestry projects were predominantly narrowly-focused such as testing multi-purpose Australian tree species on a range of sites in developing countries and then improving the quality of and access to germplasm for the most promising species. Over time, the focus of this research broadened, initially to include technical research associated with the growing, protection and utilisation of trees by smallholders, and subsequently to include consideration of social and economic issues, the incorporation of non-timber forest products, and facilitating access to and the efficiency of value-adding forest industries (Bartlett, 2016).

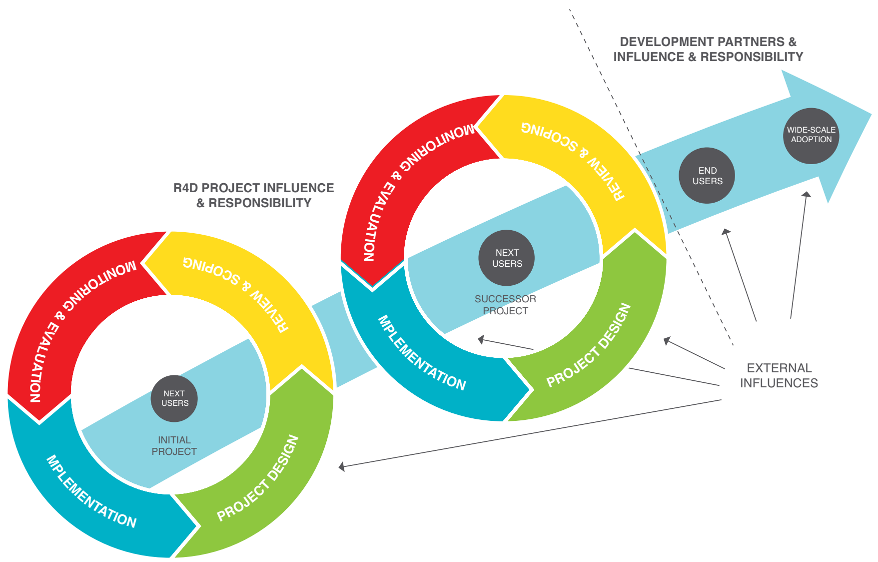
ACIAR'S APPROACH FOR SYSTEMS-BASED AGROFORESTRY RESEARCH

Bartlett (2016) described the strategic and operational components of the approach ACIAR uses for its R4D investments, which includes: focusing its investments on research priorities identified by the partner country; using scoping studies and peer review to achieve high quality project design; allowing flexibility during project implementation; and conducting mid-term and external end-of-project reviews to facilitate learning. ACIAR's systems-based approach to agroforestry research also includes the following five strategic components:

i. Understanding the connection between the planned research and the impact pathway:

The nature and extent of impacts generated by individual projects depends partly on where a project is situated on the impact pathway along the research to development continuum (see Figure 1), as well as the nature and effect of any external influences (Bartlett, 2018). The further along the impact pathway that a particular project sits, the greater the need to include mechanisms to engage a wider range of end users and national and international development agencies.

Figure 1: Influence and responsibilities in the research for development continuum (Source: Bartlett, 2018)



ii. Program and project design and duration:

ACIAR commissions its research to address research priorities in the partner countries identified through periodic country consultation processes. Each new theme of research investment is usually informed by a detailed scoping mission, while ongoing investments are informed by the findings and lessons from existing projects and external reviews. Long-term agroforestry trials are generally located on sites with good security, including research stations and private land, whereas farmer demonstration trials are widely used within projects to encourage adoption and adaptation of agroforestry by farmers. Individual ACIAR projects have a three to five-year duration and generally don't complete all the research needed to enable large-scale adoption of the improved agroforestry practices. Therefore, ACIAR often funds a program of multiple linked projects in order to achieve the intended development goal and to improve knowledge of the impacts and livelihood benefits from the research.

iii. Breadth of scope of programs and projects:

In ACIAR's approach to systems-based agroforestry research, all aspects of the integrated system, from supply of quality germplasm and implementation of agroforestry practices through to marketing and processing of agroforestry products, are potentially researchable. The scope of individual projects can be narrow or broad depending on the nature of the identified research gaps and the available funding. In designing its research interventions, ACIAR uses two different approaches:

1. Implementing a portfolio of projects in a country or a region, that address different aspects of the agroforestry production and value chain system. ACIAR then facilitates processes to share the findings and lessons between these projects, thereby generating holistic outcomes and impacts.
2. Implementing a larger more holistic project, where a range of component research topics are integrated into the project design. Such projects generally require a project leader with considerable experience in managing complex projects who has time allocated for both project management and specific research activities. These projects often have a component dedicated to knowledge management.

Ethiopian champion woman farmer Kuli Tiki with grafted avacado planted in her maize field at Tibe

iv. Composition and functioning of the project team:

ACIAR projects involve teams of scientists from Australia, and/or from the CGIAR research centres, working collaboratively with scientists and other stakeholders in the partner country. In general, the projects involve scientists from a variety of disciplines, working in a multi-disciplinary and increasingly inter-disciplinary manner. As they do not generally involve full-time appointments or expatriate placements in country, the projects require mechanisms to achieve both effective collaboration with local partners and good coordination of different contributions within the project team.

v. Review and adaptation during project implementation: ACIAR has always had a philosophy of not trying to over-design its research projects and of providing a degree of flexibility to projects to adapt the design based on implementation experiences and lessons. To achieve this ACIAR incorporates four elements of review, though not all of these are necessarily used on every project. These elements are:

1. Formal reviews within the first year when some design aspects were uncertain at the beginning. This is most commonly used at the beginning of a long-term research program, involving a new team of collaborators and the scoping mission could not determine the precise location or nature of the research trials.
2. Annual reviews by the project team of the progress and challenges together with a desk top review by ACIAR based on the project's submitted annual report. Project leaders can request changes to project activities as part of these annual reports.
3. Participatory mid-term reviews with the project team and stakeholders, to assess progress against the planned activities and to identify any changes to improve the project's effectiveness. These reviews are generally conducted by the relevant ACIAR Research Program Manager, but they may include external reviewers.
4. External reviews at the end of the project in the country, or countries, where the project has been implemented, which provide both accountability and lesson-learning functions.

The following example, from ACIAR's Trees for Food Security agroforestry project in Eastern Africa, illustrates the facilitating adaptation during implementation. The project's mid-term review identified limited access to water as a constraint to the adoption of agroforestry in semi-arid regions of Ethiopia, a factor that had been inadequately considered in the project's scoping and design activities. The project design was subsequently modified to incorporate activities investigating low-cost water harvesting options for villages, which led to greater uptake of the agroforestry innovations in the second half of the project.

KEY AREAS OF FOCUS WITHIN ACIAR'S SYSTEMS-BASED AGROFORESTRY RESEARCH

The performance of different agroforestry practices and the risks to farmers from adopting them varies with fine-scale variation in biophysical and socio-economic context (Coe et al., 2016). Ongoing research can help improve the productivity and profitability of existing systems, understand farmer attitudes towards their adoption and to identify and promote a diverse range of locally-appropriate agroforestry practices that are market-focussed and resilient under a changing climate. Some aspects of ACIAR's systems-based agroforestry research will now be further explained, using examples related to ACIAR projects.

UNDERSTANDING THE FARMING SYSTEM & PRODUCT VALUE CHAINS & THEN IDENTIFYING WHERE RESEARCH CAN BEST SUPPORT IMPROVEMENTS

When designing systems-focused agroforestry research, it is important to understand the gaps in knowledge and technologies as well as the constraints to adoption. One effective way to do this is by conducting a well-planned scoping mission, as evidenced by the following example. Teak agroforestry has become an integral part of the farming system widely adopted by smallholders in upland areas northern Laos, but it was not leading to enhanced livelihoods for farmers. An ACIAR scoping mission study (Midgley et al., 2007) identified two significant impediments limiting the economic potential offered by teak agroforestry and recommended that four issues be researched:

1. market information for teak & companion crops
2. identification of potential companion crops that can grow with teak
3. the social impacts of an expanding area of privately-owned teak smallholdings
4. the technical issues surrounding the improved cultivation of teak

ACIAR then developed a four-year project that commenced research on spacing and thinning of teak, the incorporation of non-timber forest products into teak agroforestry, and improvement of the teak germplasm available to farmers.

IDENTIFYING & ENHANCING APPROPRIATE AGROFORESTRY TECHNOLOGIES

Understanding the existing variations in farmer household wealth status, preferences and motivations aids the development of appropriate agroforestry practices. In Nepal, analysis of baseline data from 668 households, indicated that resource-poor households are more likely to adapt farming systems to include terraced-based agroforestry, while resource-rich households tend to prefer woodlot forms of agroforestry (Cedamon et al., 2017). In Ethiopia, analysis of baseline data from 687 households, found that farmers integrate many native and exotic tree species into their farming systems to meet variable farm conditions, household needs and asset profiles, adopting either farmer managed natural regeneration to meet subsistence needs or agroforestry plantings to produce fruits, timber and fodder (Iiyama et al., 2016).

Understanding tree-crop interactions within agroforestry practices is important but comparatively poorly researched. Research in Ethiopia, found that some combinations of trees and crops, such as wheat grown in a 'parkland' of *Faidherbia* trees increased grain yields, particularly in dry years (Sida et al., 2018b). Elsewhere, other combinations of maize grown with *Cordia, Croton* and *Acacia* trees significantly decreased grain yields, but farmers understood and accepted this trade-off because of the income generated from trees and the reduced required to collect firewood (Sida et al., 2018a). Research enables better understanding of tree-crop interactions and the development of models to predict crop yields in the presence of trees, as recently achieved by adding trees into the globally-calibrated APSIM family of crop models (Smethurst et al., 2017, Luedeling et al., 2016).

In most developing countries, there are hundreds of non-timber forest products that are utilised by local people which could be incorporated into agroforestry practices as another option for generating income while farmers are waiting for their trees to produce merchantable timber. Agroforestry research can be adapted to incorporate greater understanding of local knowledge about the growth and use of these products. In Eastern Indonesia, an ACIAR project identified hidden economies of locally traded non-timber forest products including many that had the potential to be value-added by small enterprises and traded in more commercial markets (Cunningham et al., 2011). Research on developing community based non-timber forest product enterprises has identified some promising opportunities and the constraints to achieving economically viable producer groups linked to commercial entrepreneurs that market the value-added products (Cunningham et al., 2017). Given the number of non-timber forest products with commercial potential and the few documented examples of commercially successful integrated timber and non-timber agroforestry practices more research is warranted.

Indonesian farmers located in a farmer demonstration trial of thinning and pruning of teak trees located at Gunungkidul.

Indonesian champion farmer, Pak Basir, from Benjala village in Sulawesi how participated in Master Tree Grower training who trains other farmers about managing trees and measuring timber to improve the financial returns from agroforestry.

ENGAGEMENT & EMPOWERMENT OF LOCAL FARMERS & PARTNER RESEARCHERS

Systems-based approaches to agroforestry research need to include effective components to engage and empower the intended users of the research, generally smallholder farmers, research partners and development agencies where the projects are being implemented. To do this, three strategies are used in ACIAR agroforestry projects:

i) Engaging farmers in research trials

To promote agroforestry adoption, an ACIAR agroforestry project in Northwest Vietnam has implemented three levels of farmer engagement. These are: Participatory Farmer Trials, where a number of 'best bet' agroforestry systems are scientifically trialled on interested farmers' land; Farmer Demonstration Trials, where farmers are provided with knowledge and seedlings to establish small agroforestry plantings that are then monitored by the project; and Exemplar Landscapes, where participating communities are supported to establish consolidated larger agroforestry plantings within landscapes (Nguyen, 2017). This approach is primarily based on classic extension and dissemination theories, but is innovative in simultaneously working bottom-up with farmers, to determine what agroforestry practices are feasible, and top-down with provincial governments to incentivise adoption and spread what works (Sinclair, 2017).

To maintain farmer motivation, the agroforestry trials often need to include components that will generate early financial returns while the trees grow to merchantable size.

ii) Capacity building

Capacity building has been identified as one of the 15 key success factors that influence the relative success of ACIAR forestry projects (Bartlett, 2018). Collaborative agroforestry research can only be successful if the research partners and the intended end users of the research develop the capacity to conduct the research and implement its findings. Therefore, a systems approach to agroforestry research needs to identify and address the gaps in existing capacity, that will constrain project implementation or adoption of findings.

For 25 years, the main focus of ACIAR's forestry program in Vietnam was directed towards supporting the domestication and improvement of Australian tree species for use in smallholder agroforestry systems (Bartlett et al., 2017). As a result of this long-term research collaboration and Vietnam's effective mechanisms for disseminating the improved tree germplasm to farmers, Vietnam now has approximately 2 million hectares of *Acacia* plantations, of which about half are smallholder woodlots grown as part of the farming system. During this long-term program of collaborative research, ACIAR supported significant capacity building activities with partner scientists from the Vietnam Academy of Forest Sciences (VAFS), including within project training and post-graduate training. Training was provided on specific and general research methods, leadership and research strategy, project planning and management, scientific writing and communication skills (Morris et al., 2017). All of these have helped develop a sustainable national research capability that now continues the research and development needed to sustain Vietnam's vibrant smallholder forestry economy with little need for external support.

iii) Supporting scaling of adoption

One of the greatest challenges in achieving widescale adoption of agroforestry technologies, within the operating context of research projects, lies in how effectively they reach and engage large numbers of smallholder farmers. Two promising approaches to help address this challenge, that are being trialled in some ACIAR agroforestry projects, are Rural Resource Centres and the Master Tree Grower program.

A Rural Resource Centre (RRC) is a training and demonstration hub, managed by the local community, generally outside the formal extension system, that creates opportunities for farmers to share experiences and receive training and quality planting materials (Degrande et al., 2015). In Ethiopia, an ACIAR project established three RRCs which include a training space and nursery facilities. The Batu RRC is operated by a farmers' cooperative consisting of seven women and five men, who were previously unemployed landless people. In 2015, the RRC provided training to 247 farmers, 215 students and 42 government extension officers and also produced 54,100 fruit and timber seedlings, as well as high-value vegetables, which generated USD$ 4,861 in revenue for the cooperative members (Mekuria et al., 2016). The Government of Ethiopia has been so impressed with the effectiveness of the project's three RRCs that it intends to convert all of its 30,000 or so Farmer Training Centres into RRCs, to facilitate more effective adoption of agroforestry.

The Master Tree Grower scheme is an Australian agroforestry outreach initiative that both equips individual farmers with information to make decisions on tree species and practices and facilitates them to provide mentoring to other farmers (Reid, 2017). ACIAR agroforestry projects in Indonesia and Vanuatu have been exploring the applicability of this scheme to situations in developing countries where farmers don't get the best returns from tree growing and local extension services are weak. In 2014, an ACIAR project in Indonesia provided Master Tree Grower training courses to 90 farmers (79 men and 11 women) across three provinces, adapting the program into the Bahasa language and strengthening the focus on improving understanding of the market requirements for high-quality timber. In 2016, an evaluation of 62 farmers who had participated in the training found that over 90 percent of the farmers had used the knowledge gained to change some of their practices, including implementing pruning or thinning, measuring their trees and the way they marketed their timber. It also found that, for every farmer trained, an additional four farmers received knowledge and skills through the farmers' networks (Muktasam et al., 2019). This is in line with the spread and impact of farmer-to-farmer training as a dissemination strategy for agroforestry more generally (Kiptot and Franzel, 2015).

UNDERSTANDING & ENHANCING VALUE CHAINS, ENABLING MARKET ACCESS & ADDING VALUE TO FOREST PRODUCTS

Many ACIAR projects focus on understanding and addressing constraints or inefficiencies in the value-added forest product value chains, or access to these markets. Both of these aspects limit the livelihoods that farmers can generate from agroforestry products and ultimately farmers should receive higher prices for products destined for value-added processors. Furthermore, many smallholders have limited skills in engaging private sector actors who control the trading and processing of the agroforestry products (Perdana and Roshetko, 2015). Undertaking research to improve farmer access to high-value markets, to improve the efficiencies in the existing value chains and to enhance value-added processing are key components of a systems-based approach to agroforestry research. Many private sector companies, including Nestlé, also seek to add value along the value chain by supporting research and programmes to improve the quality and quantity of farmer production systems as well the local manufacturing of quality products (Bee et al., 2015).

In Indonesia, on the island of Java, large numbers of farmers have adopted agroforestry systems involving high-value timbers such as teak and mahogany, which they sell through middlemen to enterprises producing wooden furniture. The Indonesian furniture industry value chain is long and complex: from the smallholder tree growers, to product manufacturers and on to the furniture retailers and exporters. An ACIAR project facilitated research on value chains linked to the furniture industry in the town of Jepara. The researchers and industry stakeholders developed four strategies to strengthen the industry structure, enhance value-adding and improve livelihoods of farmers and workers in the furniture enterprises (Purnomo et al., 2011). A second ACIAR project worked with furniture manufacturers to enhance the effectiveness of sawing, drying and manufacturing processes utilising small-diameter logs grown by smallholders (Ozarska and Sugiyanto, 2015).

ENGAGEMENT OF THE POLICY & PRIVATE SECTOR ACTORS

The ability of farmers to adopt agroforestry or to market its products can be constrained by gaps in policies or policy implementation (Simelton et al., 2017), as well as by the inability of smallholders to comply with existing regulations related to growing and marketing timber (Smith et al., 2017) which are often very complex (Maryudi et al., 2015). All aspects of agroforestry product value chains beyond the farm gate are largely influenced by private sector actors who are often not aware of the inefficiencies in value chain that limit returns to both farmers and other value chain actors. Therefore, a systems-based approach to agroforestry research that incorporates components related to policy or value chain analysis will need to actively involve policy and private sector actors if the findings are to be understood by the relevant actors and have a good prospect of being adopted.

CONCLUSIONS

Systems-based agroforestry research is one of the most important parts of ACIAR's forestry research program and much has been learned over the past 35 years about undertaking effective research that leads to significant impacts. Understanding research and development gaps from the farm to the product processor, having well designed projects and long-term programs which build capacity and engage and empower the partners and intended users of the research are critical factors that influence success and impacts. An important lesson is that adoption of agroforestry can be enhanced by the use of innovative low-cost mechanisms that disseminate knowledge to farmers about agroforestry and the markets for its products. Finally, because of the complexity of and variation between agroforestry options and operating environments, as well as the inefficiencies in many existing practices and product value chains that limit livelihood benefits, there is an ongoing need to fund systems-based agroforestry research.

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A Vietnamese farmer collaborator, Mr Tien, with an ICRAF researcher in a complex agroforestry system trial, involving late-fruiting longan, fodder grass & maize, located at Sonh Thinh in Vân Chãn District

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CUNNINGHAM, A. B., INGRAM, W., KADATI, W. & MADUARTA, I. M. 2017. Opportunities, barriers and support needs: micro-enterprise and small enterprise development based on non-timber products in eastern Indonesia. Australian Forestry, 80, 161-177.

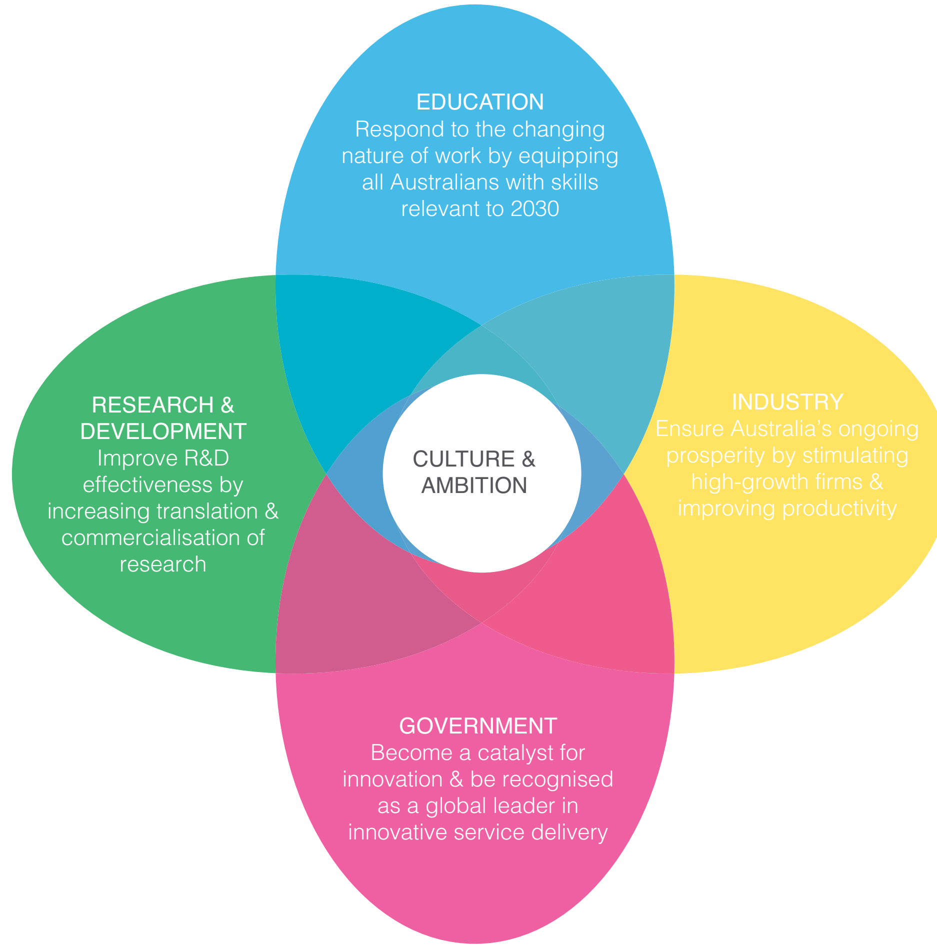
This paper describes research from eastern Indonesia related to the development of medium, small and microenterprises utilising non-timber products from forests and agroforests. It describes methods used to assess different categories of trade in non-timber products, presents results that identify products sold in large-scale and niche markets, and identifies a framework for improving the efficiency of development activities fostering opportunities for smallholders and small private sector enterprises.

IIYAMA, M., DERERO, A., KELEMU, K., MUTHURI, C., KINUTHIA, R., AYENKULU, E., KIPTOT, E., HADGU, K., MOWO, J. & SINCLAIR, F. L. 2016. Understanding patterns of tree adoption on farms in semi-arid and sub-humid Ethiopia. Agroforestry Systems, 91, 271-293.

This paper presents a novel systematic method for characterizing complex patterns of tree cover on farms, including both indigenous practices and tree planting for commercial purposes. Multi-variate analysis is used to identify associations between distinctive patterns of tree adoption on farms and ecological and socioeconomic factors that determine farmers' tree adoption strategies.

ROSHETKO, J. M., ROHADI, D., PERDANA, A., SABASTIAN, G., NURYARTONO, N., PRAMONO, A. A., WIDYANI, N., MANALU, P., FAUZI, M. A., SUMARDAMTO, P. & KUSUMOWARDHANI, N. 2013. Teak agroforestry systems for livelihood enhancement, industrial timber production, and environmental rehabilitation. Forests, Trees and Livelihoods, 22, 241-256.

This paper reports research on understanding the contributions of teak agroforestry to smallholders' livelihoods in Indonesia. The methods involve household baseline studies, focus group discussions, rapid market appraisals and the use of farmer demonstration trials. It finds that Indonesian farmers cultivate teak as one component of their farming system and identifies factors that constrain the productivity of the teak component.



Innovation and Science Australia 2017

Participatory methods: women from a water user group measuring a canal being re-excavated for dry season irrigation, Bangladesh

ADDRESSING RESEARCH COMPLEXITY: ANALYSING PATHWAYS TO IMPACT AND USING TRANSDISCIPLINARY APPROACHES

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DR EVAN W. CHRISTEN undertook research in irrigation, drainage and wastewater management for 17 years with the Commonwealth Scientific and Industrial Research Organisation (CSIRO). He was then the Research Program Manager for Land and Water Resources at the Australian Centre for International Agricultural Research (ACIAR) for 5 years. The program projects included soil and water management in rainfed agriculture, improving irrigation productivity and analysis of institutional and social aspects of local and regional water management. The projects were in South Asia, Mekong region and Africa). He is now a Director of Penevy Services Pty Ltd. undertaking research mostly in Africa.

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DR MICHAEL MITCHELL is a Research Fellow with Charles Sturt University's Institute for Land, Water and Society (ILWS). He helps coordinate a four-year ACIAR project on improving groundwater management in Pakistan with the aim of enhance farming family livelihoods. Michael was previously employed as a Research Fellow with the National Environmental Research Program's Landscapes and Policy Hub (2012-2015), and as a Research Fellow with Australia's National Centre for Groundwater Research and Training (2009-2012). Michael's doctoral dissertation (CSU, 2005-2008) involved collaboration with Murrumbidgee Irrigation in NSW to improve the company's use of 'triple bottom line' reporting.

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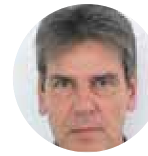
https://www.researchgate.net/profile/Michael_Mitchell18



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DR ROTH has a PhD in soil physics from the University of Göttingen, Germany and over 30 years of research experience in tropical land and water management. In the past 15 years, his research interests focussed on natural resource management, climate adaptation and social inclusivity of farming communities in South and Southeast Asia. A central feature of his work is to integrate social sciences with biophysical scenario analysis and to map theories of change to enhance research impact. Applications of this work include the SIAGI project (www.siagi.org) and his role as coordinator of CSIRO's Great Barrier Reef related research portfolio.

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EDWARD (TED) ROWLEY (BSc. Agricultural Science, University of Western Australia) is currently Director of Strategy Evaluation and Engagement for Development Pty Ltd with over 25 years of experience in international development activities. Ted's skills lie in;

- Designing national policies, strategies, monitoring/reporting plans and implementing monitoring and evaluation, reporting and improvement systems for policy
- Utilising participatory processes in 'outcomes mapping' or 'Program Logic' design techniques to support program/project design, monitoring planning and reporting by outcomes;
- Developing and reviewing monitoring systems based around defining users and uses for monitoring and reporting information, performance questions, indicators and quantitative/qualitative methods

ABSTRACT

This paper outlines the experience of the Australian Centre for International Agricultural Research (ACIAR) in developing and managing research for development projects concerning land and water resources. The complexity of the contexts in which such research is undertaken has resulted in two discernible shifts. First, to more effectively guide project design and implementation, there has been a shift to focus on research for development aims in terms of what can be achieved by the end of the project, and the project's intended longer term impacts. Improved use of impact pathways analysis has enabled projects in complex contexts to be better designed and evaluated for improvements. Second, there has been a move from interdisciplinary to transdisciplinary approaches that can put farmers and land managers firmly at the centre of the research. These shifts have led to an appreciation that research will need to more strategically address issues of equity in development.

INTRODUCTION

The Australian Centre for International Agricultural Research (ACIAR) aims to achieve more productive and sustainable agricultural systems in developing countries by facilitating international research partnerships. The goal of ACIAR's program on Land and Water Resources (LWR), recently refocussed and renamed as Water and Climate, is to improve natural resource sharing and management to benefit smallholder, landless and marginalised farming families, and to offer strategies for climate change mitigation and adaptation. To progress towards this goal, there are a large number of researchable issues from field to landscape scale that traverse biophysical, social and economic dimensions. Perspectives from multiple academic disciplines need to be incorporated to investigate land and water management issues in a way that is tailored to each local situation. Local research partnerships have therefore been identified as critical to building shared understandings of the situations being investigated.

Investigations into land and water resource management need to take into account the complexities of social systems co-evolving with natural systems (Liu et al., 2007), thus requiring use of interdisciplinary approaches (approaches that traverse and enable integration across academic discipline boundaries for a common research objective – Tress et al., 2005). The program's reliance on partnerships means such approaches are increasingly extending to become transdisciplinary approaches (approaches that traverse beyond academic boundaries and enable integration across disciplines and with actors in society for a common research objective – Tress et al., 2005). The most effective LWR projects have thus needed to understand complexity (Jakimow, 2013), use participatory approaches (Maheshwari et al., 2014), and enable project partners to understand and articulate pathways to impact (Stone-Jovicich et al., 2015). Impact pathways analysis has become a crucial means to communicate and evaluate progress towards shared research objectives.

This paper first makes the case for why research for development in agriculture and natural resource management needs to understand complexity. It then explores implications for research design, how to improve delivery by appreciating impact pathways, and how strategies for participation and transdisciplinarity can be improved. The paper relies on the authors' combined experiences: two of whom (Christen and Roth) have been as LWR Program Managers, and the other two (Mitchell and Rowley) are actively championing the shifts that this paper describes. We use examples from our experiences to illustrate our reflections on these shifts. These examples are not intended to convey the entirety of the program's experiences of these shifts.

UNDERSTANDING COMPLEXITY: ISSUES AFFECTING RESEARCH FOR DEVELOPMENT IN LAND AND WATER RESOURCES MANAGEMENT

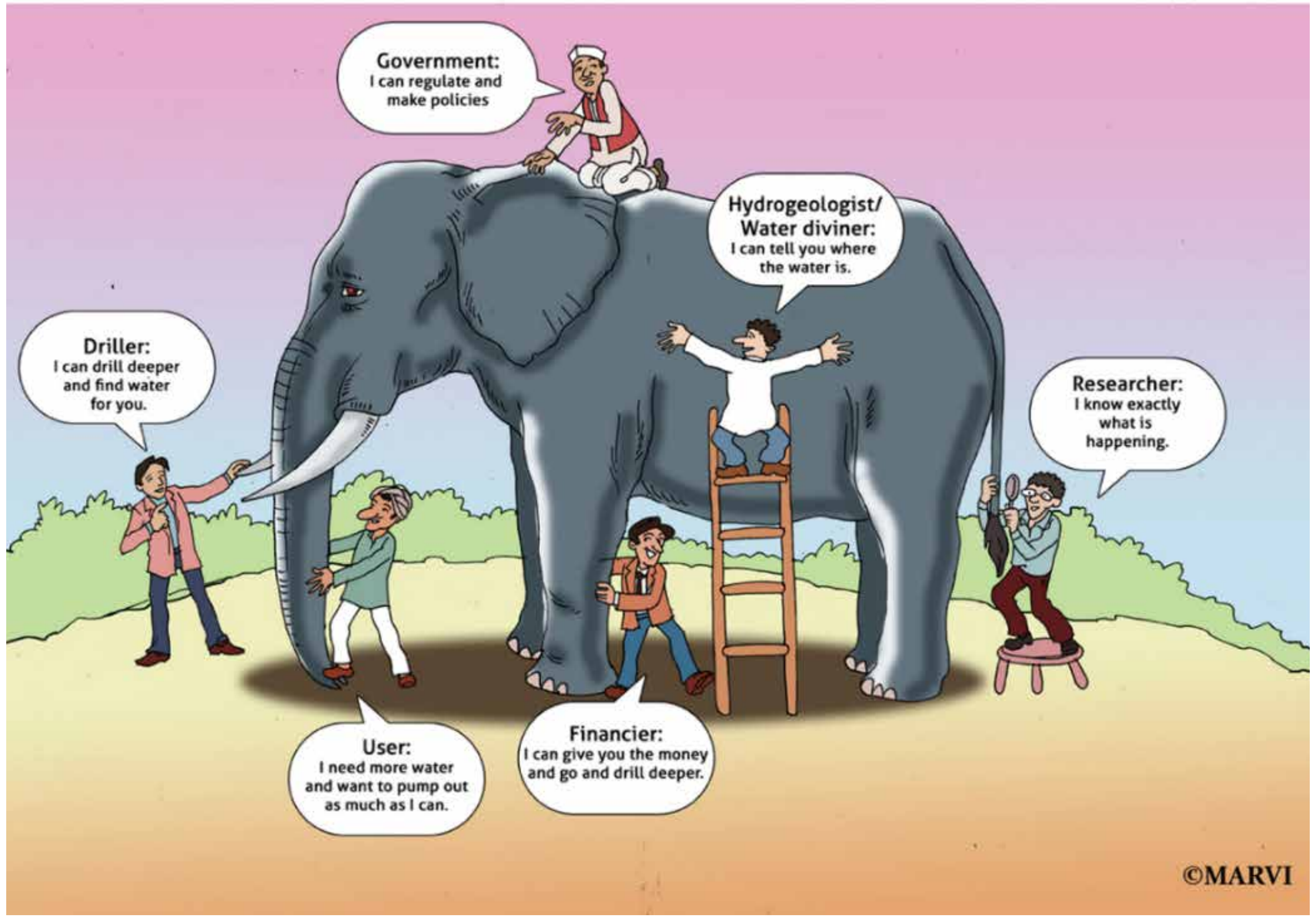
Globally, scarcity and degradation in quality of surface and groundwater affects most developing countries. By 2025, as much as 66 per cent of the global population is projected to face different forms of water scarcity (WWAP, 2012). Similarly, land degradation (erosion, fertility decline, structural decline, salinisation, acidification) is thought to affect approximately one third of the world's cropped land (ELD Initiative, 2015). These effects predominantly impact the most vulnerable – the rural poor – given their heavy dependence on land and water resources for sustenance and livelihoods. Those with poor or no access to these resources are often left behind (Molden, 2007).

A basic factor driving resource scarcity and degradation is competition for these limited resources from increasing populations, expanding economies, and demand for more refined foods and increased meat consumption. Such competition leads to unsustainable management practices. Climate variability and change place further pressures on land and water resources, and creates further uncertainty about their future management. Most agro-climatic regions are now experiencing some form of climate change, already making agronomic decisions more difficult for farmers, and water management decisions more difficult for authorities (Aggarwal et al., 2018). The complex interlinkage of all these factors means that LWR investigations have often been driven by objectives of enhancing food security and livelihoods, maintaining ecosystems, and an increasing emphasis on inclusion and equity.

From ACIAR's experience in LWR research, five broad issues have contributed to an appreciation that interdisciplinary project design is needed to tackle complexity for development outcomes:

1. Improved water management is primarily directed at increasing water use productivity, which then enhances land profitability. However, research to enhance agricultural productivity needs to be combined with research that improves smallholder engagement with value chain analysis in order to increase their incomes (Pittock et. al., 2017; Collins et al., 2016).
2. Water use is demonstrating increased efficiency and productivity, yet sustainability is still compromised by ever increasing demand, known as Jevon's paradox (Dumont et al., 2013). Managing water demand through innovative technical, social and policy approaches is therefore critical.
3. Improved land management also requires increasing agricultural productivity and profitability whilst maintaining soil fertility. This requires a sound understanding of land capability for different types of agriculture and the most appropriate agricultural and land management techniques. Developing local participatory approaches to land use is critical to support national policy options (Kutter and Ulbert, 2009).
4. Agricultural development suffers from inequitable outcomes. Farmers have variable economic, social, human and natural resources, resulting in variable capacities to participate in research and to adopt and adapt results. Research for agricultural development needs to explicitly recognise this and aim for more inclusive agricultural development that promotes equitable access to land and water resources by those marginalised due to poverty, gender, age, disability, tribe, caste, religion, etc. (Brown and Kennedy, 2005; Darbas et al., 2013; Williams et al., 2016).
5. Sustainable development, in the sense of biophysical, economic and social factors, requires integrated approaches that consider issues of scale: farm, watershed and basin, and the interdisciplinary nature of the problems (Lefroy et al., 2012). Single discipline projects are likely to ignore system complexity leading to ineffective interventions on the ground (Midgley, 2003).

Picture 1: Complexity in agriculture: a farmer of a salinity affected property looks on to his neighbour's proprty where sugar cane residue is being burnt. ACIAR researchers looking on with him suggest he ask to harvest the residue and use it as mulch to help restore his property. Simple idea, complex in delivery (Michael Mitchell, 2018).



Picture 2: The complexity of groundwater management: an ACIAR project in India metaphorically depicting the challenge of multiple stakeholders with multiple perspectives (Maheshwari et. al, 2014).

The complexity of such agricultural research for development contexts cannot be tackled by project teams with insufficient or single dimensional experience, *see picture 1.* Achievement of 'end of project' outcomes depends on multiple dimensions, events and stakeholders along the impact pathways, with lessening control and influence of project management through time. Figure 1 shows different levels of complexity ranging from the simple to chaotic. Research for development, when it is genuinely trying to lead to change on the ground, is firmly in the 'complex' quarter. On occasion, it may also operate in the 'chaotic' quarter, such as in a post-conflict situation. Project teams need to recognise they are operating in complex contexts, with dynamic linkages across biophysical, economic and social systems, and with multiple stakeholders who will engage and respond in different ways, *see picture 2.*

Different levels of complexity are described below (adapted from Snowden and Boone, 2007)

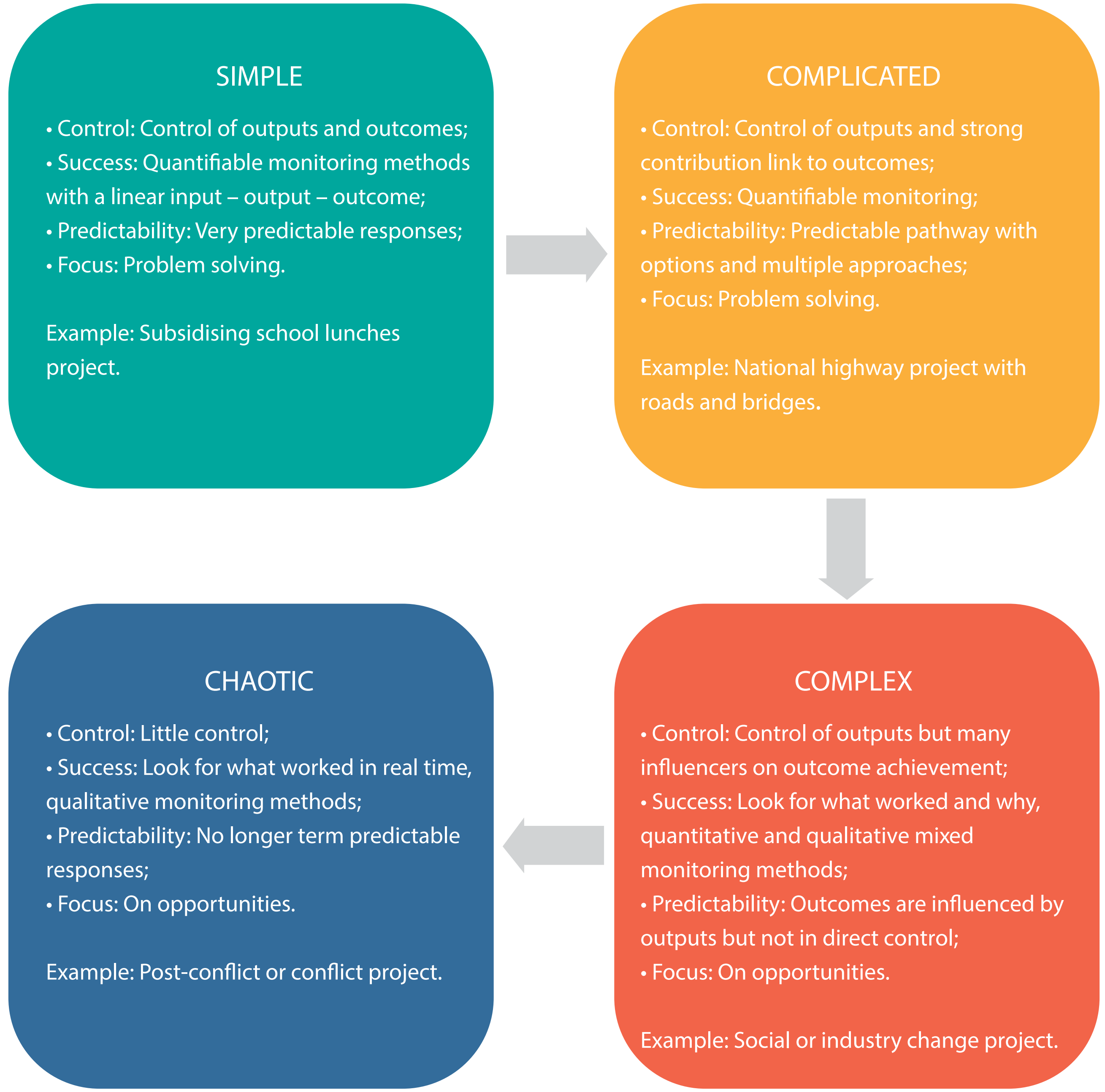


Figure 1: Levels of complexity. Adapted from Snowden and Boone (2007).

IMPACT PATHWAYS

In the context of land and water resources management and agricultural research interventions, impact pathways analysis is increasingly used to help build project designs, ensure stakeholders have shared understanding of the project pathways to impact, and provide frameworks for adaptive management and for monitoring, evaluation and reporting plans and actions. A range of approaches are used to describe and map outcomes. Terms and approaches such as 'program logic', 'theory of change', 'outcomes mapping' and 'impact pathways analysis' are often used interchangeably (see boxed explanations).

To help project teams address the complex contexts in which they work, ACIAR has, over recent years, explored the use of participatory approaches in developing impact pathways analysis (IPA) with project stakeholders at the project design stage. Author Rowley has been key in leading ACIAR to adopt this approach. The following explanations are drawn from material provided to ACIAR project teams to help them undertake participatory IPAs.

Conducting a participatory IPA allows project designers to explore the complexity of the contexts in which they are trying to effect change with key stakeholders (Douthwaite et al., 2007a; 2007b). The project team needs to think through what change from the project will look like in a localised, credible way, avoiding overly ambitious descriptors for goals and aims and generalisations, and keeping the project grounded and focused. It is a structured process, promoting learning and providing a framework for transdisciplinary 'action–research' to achieve the planned end of project outcomes. It allows the project team and beneficiaries to co-construct their impact pathways, *see picture 3.*

Picture 3: Participatory impact pathway analysis: a group discussing key assumptions embedded in their analysis (Michael Mitchell, 2017).

To develop impact pathways, it is more strategic to start by clarifying intended end of project outcomes, then working backwards through causal intermediate outcomes, research outputs, and activities. The impact pathways need to be developed as a facilitated activity to guarantee inputs from relevant project partners and participants. It is ideally undertaken during project development, at inception, and refined annually as part of an adaptive management process. This helps project partners evaluate or clarify the logic of the project intervention, and provides the basis for a plan for learning and improving through monitoring, evaluation and reporting project performance. Benefits include:

- Improved clarity of purpose and a shared vision of what the project is trying to achieve.
- Increased ownership of proposal designs by in-country partners.
- A shared understanding of how project components fit together to bring about end of project outcomes, and how the work of project partners fits within the bigger picture.
- A commonly understood format for a monitoring, evaluation, reporting and learning plan, which also can improve efficiency of reporting systems.
- A greater depth of knowledge and cultural diversity.
- Better identified processes of individual, group and institutional change in practice, capacity and access to information, which can also support continuous learning.
- Provides monitoring information to support communication actions.

A monitoring, evaluation and reporting and learning (MERL) plan can also be built that:

- Identifies assumptions (project risks) inherent in the project design.
- Identifies users and uses for reporting information and research outcomes.
- Provides design options for answering key monitoring and evaluation questions, including identification of key performance indicators.
- Progressively collates documents and interprets qualitative and quantitative evidence for reporting and communication.

ACIAR projects that use impact pathways analysis for project evaluation purposes are more effectively able to avoid project reviews that become lost in the detail of research results achieved at the time of the review. Recent LWR examples of project reviews show that they become more forward-looking when impact pathways analysis is used to frame discussions. This is because they require project participants to interpret how their research results are contributing to intended end of project outcomes. This is particularly pertinent for projects partnering with government and non-government organisations, as explored further in the following two sections.

PARTICIPATORY APPROACHES: EVOLUTION FROM INTERDISCIPLINARY TO TRANSDISCIPLINARY TEAMS

Maximising stakeholder participation, especially of next users and other research beneficiaries, needs to be an integral part of the project strategy. This stems from an acknowledgement that:

- The research team does not have all knowledge, learning, data and resources in a particular area and that other stakeholders have much to contribute in understanding and intervening in complex situations.
- Engaged stakeholders treated as equals by research teams can contribute greatly to project success including knowledge exchange, increased skills and confidence, production of useful and credible outputs, and increased post-project likelihood that end-of-project outcomes are scaled out and up.

ACIAR's funding arrangements require and nurture partnerships. Funds are provided for research activities with the expectation that in-country partners commit staff time as in-kind contributions. This means that partners – both as organisations and individual team members – need to be committed to the project and its activities. Over time, this has entailed partners co-designing research objectives, delivery strategies and intended outcomes. Many ACIAR projects initially built partnerships with universities and other research institutes in recipient countries. In ACIAR's LWR projects, the increased attention on pathways to impact has led to an increased need to engage government and non-government organisations as project partners. Inclusion of such partners in the co-design of projects is driving this shift in ACIAR towards transdisciplinarity; a shift that builds on a wealth of Australian and ACIAR experiences undertaking and evaluating transdisciplinary research (e.g. Roux et al., 2010; Maheshwari et al., 2014).
As a result, ACIAR's template for project proposals, emphasises the need to consider next users (partners who will use and promote research outputs to end users), end users (as the intended benficiaries of the research for development process), and more recently (since 2016), explicit description of impact pathways (to explain how the research will contribute to overall project goals).

The need to engage research beneficiairies as co-researchers is gaining prominence, and some ACIAR-LWR projects are considering how farming communities engaged through the research process can also contribute to research design, delivery and outcomes, especially as it affects them. For example, the "Promoting socially inclusive and sustainable agricultural intensification in West Bengal and Bangladesh" project (SIAGI – www.siagi.org) has taken a proactive approach to engage farmers through case studies (Croke et al., 2018). The project's emphasis on co-learning between farmers and researchers, and designating farmers as co-researchers, has proven to be very powerful (Croke et al., 2018; and see picture 4). It has allowed landless and other marginalised smallholders, including women-headed households, to influence project design by exchanging ideas on appropriate opportunities through which they can benefit from agricultural intensification.

Farmers can also be engaged so that they can help lead research design. For example, the ACIAR project "Water harvesting and better cropping systems for smallholders of the East India Plateau" undertook participatory research to evaluate climate risk in the rice-fallow system, developed options for managing risk, and evaluated ways to intensify and diversify cropping. A key project partner was the Indian NGO 'Professional assistance for development assistance' (PRADAN). They develop local capacity for innovation through 'Self Help Groups'. In the project, they combined with Australian and Indian agronomists and hydrologists to ensure that women farmers played a key role in implementing the research. Ultimately, the women farmers were empowered to undertake their own research, deciding on the research to be taken for that season and collecting the data. This direct input proved critical in deciding what crops to grow and treatments to be researched that met farming family needs and suited their local markets. This approach meant the project results were readily adoptable; >20,000 farmers now having taken up direct seeded rice and vegetable growing. These approaches are being further out-scaled by PRADAN and local government (Bellotti, 2017).

Farmers can also be involved in sophisticated research approaches such as crop modelling. In the ACIAR project –'Adapting to Climate Change in Asia (ACCA) various adaptations of rice-based cropping systems to manage climate variability were researched. All adaptations were generated through detailed discussion with farmers and local NGOs and were then tested in farmers' fields before being evaluated through cropping system simulation analysis (Hochman et al., 2017). The adaptation options that were trialled in the villages were simulated using local soil and long term historical weather data and the results of the simulations 'reality checked' with the farmers.

ACIAR projects in southern Africa and south Asia are demonstrating how collaborative learning approaches enabling farmers and villagers to share experiential learning are the most effective means for uptake and dissemination of water conservation tools and methods (Maheshwari et al., 2014; Stirzaker, et al., 2017). The ACIAR project "Managing aquifer recharge and sustaining groundwater use through village-level intervention" undertook research that facilitated village-level participation in the use of models and tools for improving groundwater supplies and reducing groundwater demand. Farmers and other affected stakeholders were directly engaged in these activities, including through local schools. A unique feature of the project was the collection of scientific data by citizens through the engagement of Bhujal Jankaars (BJs), a Hindi word meaning 'groundwater informed' volunteers. With appropriate training and capacity building, BJs monitored groundwater levels and quality, making sense from a village perspective of what was happening to village groundwater availability. By having local farmers (BJs) monitor their groundwater resources and sharing this information with the community, villagers were able to discuss their groundwater situation in an objective way. This led to constructive dialogue on cooperative management of the groundwater resource (Maheshwari et al., 2014).

In such approaches, farmers learning together is critical. Providing farmers with opportunities to measure and collect data on aspects of their crop production and discuss the results together enables development of locally appropriate changes to their practices, leading to significant reduction in irrigation use (Hochman et al., 2017; Nidumolu et al., under review). What is especially significant is that such projects are not just enabling behavioural change, but that such change is driven by changes in attitude, coupled with a greater appreciation of community ownership of shared water resources, including groundwater (Varua et al., 2016; 2017).

The learning for the researchers in such project teams also changes their perspectives of situations being encountered and potential research for development outcomes. These changes result in the understanding that projects are developing people rather than just farming systems or technologies. This learning also changes how researchers see the activities of others. They are more able to appreciate that allowing farmers to learn for themselves builds their capacity to modify, adapt and monitor their farming systems in line with their evolving needs and resources (Ramsay et al., 2017).

Some ACIAR projects have found that an effective means to engage farming families is through non-government organisations (NGOs) (e.g. Croke et al., 2018). Having effective partner NGOs as part of the project team can help reveal social dimensions that Australians and in-country partners may not otherwise appreciate. The SIAGI project has also shown that local NGO engagement can provide techniques for ethical and respectful engagement with farming communities. By selecting NGOs that focus primarily on addressing the needs of landless, women and other marginalised groups helps mitigate unintended outcomes of inequitable development. For example, collaboration with NGOs in India and Bangladesh facilitated creation of women's self-help groups (Croke et al., 2018). One of the Bangladesh-based self-help groups established small reservoirs on the polder dykes, expanding water sources for crops during the dry season, especially for family gardens, as well as providing relatively cleaner water for domestic use.

The best NGOs have many years of experience in understanding and implementing practical approaches that work. In SIAGI's case, their engagement with the NGO Centre for Development of Human Initiatives (CDHI), resulted in the researchers and project leader learning of better approaches to community engagement and a significant shift in project orientation to adopt CDHI's practice of ethical community engagement (Roy et al., 2017, p. iv). Some of the principles that drive approaches of local NGOs include explicit recognition of the need for social inclusion, the primacy of building local capacity of rural communities to access and mobilise internal and external resources, and participatory technology selection and adaptation. These are all critical aspects that enables a research team to benefit from properly adapted and targeted research.

The need for and emphasis on partnerships in LWR projects have led to formative co-design of projects at the outset, and reference to partnerships as key to impact pathways and end of project outcomes. This entails a shift towards transdisciplinarity. When the complexity of the project environment is understood, a participatory and well formulated impact pathways analysis is developed, and the need for participatory approaches in the project strategy is accepted, the result will motivate a shift to a transdisciplinary mode. While in the past the technical complexity of land and water resource management called for an interdisciplinary approach, it is the transdisciplinary teams that are more capable of addressing complex social-ecological issues. They are likely to be more innovative, recognise different ways of knowing, empower collaborating non-researchers and leave a positive legacy. Also within the project there is better energy as people challenge each other and learn as a result.

As discussed above, the complex nature of land and water management projects means knowledge generation should not be confined to the researchers themselves; it is also about the inclusion of development NGOs and also mixing together university and government staff from multiple departments and/or ministries who under normal circumstances would not work together. This mix leads to discussions about the real 'boundary' issues that are often the most difficult to deal with as a researcher cannot see or do what a government agent can, who cannot see or do what an NGO does. The different views, powers, contradictions and gaps between the various stakeholders become readily apparent and have to be addressed.

However, in our experience, ACIAR's LWR projects often encounter reluctance among staff in universities and government agencies to engage in participatory and transdisciplinary approaches. This can be due to a lack of appreciation for participatory approaches and empowerment, and the fear of the unknown. Approaches in the past gave such staff greater control because they were undertaking technical interventions and building infrastructure rather than by building capacity among farmers and local stakeholders. There are also a range of other well-documented barriers to implementing transdisciplinary approaches (e.g. see Mitchell et al., 2017).

Learning by all the participants in a research for development project is important but also challenging, in that an understanding of learning for all participants has to be built into project operation and management. Ramsay et al. (2017) state that *"Changes in the cognition of project participants not only changes their understanding of what is happening but also changes what participants believe should be researched. These changes make the project dynamic and more complex posing additional challenges for project management in the field and the relationship between the project team and funding body"*.

The above puts the onus on research funders and managers to be flexible to adapt to team learning and allow projects to evolve from initial conceptions into better targeted formulations as partner and stakeholder understanding of the situations being faced increase. Assessing this learning can be explicitly undertaken by reviewing the project impact pathways analysis, including as part of annual and mid-term project reviews. In the case of the ACIAR project "Improving groundwater management to enhance agriculture and farming livelihoods in Pakistan" project, framing the mid-term review around intended end of project outcomes enabled appreciation for government irrigation department officials taking the lead in developing groundwater models, rather than having that work contracted out to university researchers. The project reviewers had the opportunity to understand how that engagement was transforming the attitudes and practices of government departmental staff so engaged, and greater ownership and use of the models, associated data, and how both could be used for decision support with the ultimate intended beneficiaries. Such benefits were appreciated as far outweighing the time involved, time that could have been significantly curtailed if university researchers produced the models themselves, and then handed them over to the departments.

FUTURE DIRECTIONS IN R4D IN LAND & WATER RESOURCES IN ACIAR: THE SIAGI EXAMPLE

We have argued that the complex nature of research for development in natural resource management requires a transdisciplinary systems approach that integrates social, institutional and biophysical research methods, explores bridging between community and policy scales, and engages key next-users (NGOs, government agencies, private enterprises) as integral project partners. Such an approach is currently being taken up in ACIAR's aforementioned SIAGI project.

Intensification of agriculture by use of high-yielding crop varieties, better animal breeds and animal husbandry, aquaculture, fertilisation, irrigation, and pesticides has contributed substantially to the tremendous increases in food production over the past 50 years. In aggregate terms, agricultural intensification is undeniably increasing food production and ensuring food demand is met. In broad terms it is also helping alleviate poverty. However, this has come at the cost of an increasing social dichotomy between more affluent landholders and socially disadvantaged groups such as landless or marginal smallholders, women-headed households, and tribal minorities. This is because affluent landholders and landlords are in a stronger position to capture the benefits of agricultural intensification. Consequently, these marginal groups are much more exposed to unintended consequences of agricultural intensification.

This has led the SIAGI project to develop a research strategy that addresses the following research questions:

- How and why are different rural livelihoods affected by agricultural intensification in key agro-ecological settings in the Eastern Ganges Basin?
- What is the nature of social exclusion or adverse incorporation? Who gains, who loses, how and why?
- What are the livelihood risks and how can resilience of disadvantaged households be strengthened?
- How can institutional arrangements and power structures be redesigned to better support disadvantaged households, in particular women?

- What are the development strategies that could lead to increased social inclusion and a reduction in unintended consequences of agricultural intensification?
- How can insights in the above be used to inform next users (NGOs, policy makers and public-private partnerships) and lead to better design of and implementation in future policy and development interventions?

To explore these questions, the SIAGI project is developing research methodologies that combine a range of quantitative and qualitative methods with scenario analysis tools to engage with next users to implement socially inclusive policies and engagement processes, and to engage with end users to help them explore options and make choices (www.siagi.org).

CONCLUSION

This paper has offered examples of the evolution in and approaches to research for development in the ACIAR Land and Water resources program. This has culminated in most of the more recent projects in the program being designed as transdisciplinary with a strong analysis of their impact pathways with the involvement of a broad range of stakeholders at the planning stage. The ACIAR management team believes that the results from these transdisciplinary projects show that they are more impactful than multidisciplinary projects and those projects that don't focus on their impact pathways. The involvement of good NGOs has helped increase impact from projects and has also resulted in complete changes to project methodologies, for example increased emphasis on ethical community engagement.

The need for equitable and inclusive development has led to changed research for development approaches such as the SIAGI project described above that are actively seeking out methods to effectively engage the marginalised in agricultural development and natural resource management.

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Papers of particular interest have been highlighted as:

*** Outstanding - for foundational concepts*
** Excellent – for case studies*

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Community soils activity, Tang Robang Village, Cambodia

SOIL AND LAND MANAGEMENT RESEARCH IN CAMBODIA: OPPORTUNITIES FOR STRENGTHENING COLLABORATION AND BETTER INTEGRATION OF DISCIPLINARY IDEAS FOR GREATER IMPACT

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BIOGRAPHICAL NOTES

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Davina Boyd is a development practitioner and researcher. She has worked with not for profits, the private sector, and universities to design, manage and evaluate community and international development projects with a strong focus on building individual and institutional capacity. She has spent the last six years working on agricultural development research projects with a specific focus on smallholder farmer capacity to: engage with markets, intensify their farming systems and utilise suitable and site specific management practices. Currently Davina is employed as a Research Fellow at Murdoch University working on four ACIAR projects in Cambodia, Laos and Bangladesh.

ABSTRACT

While Cambodia's economy has undergone impressive growth over the last 20 years, poverty reduction and improved food security remain important agendas for Cambodia. The Australian Centre for International Agricultural Research (ACIAR's) portfolio in Cambodia focuses on reducing poverty and improving smallholder farmers livelihoods through research into more productive and sustainable agriculture. These issues are mulitifaced and complex and there is growing recognition that transdisciplinary research and in particular collaboration are important for developing practically relevant outcomes to respond to these challenges. This paper draws on transdisciplinary collaboration literature and experience of a researcher participating in ACIAR Soil and Land Management (SLaM) projects in Cambodia; it highlights some of the challenges to collaboration as well as opportunities for strengthening it to enable better integration of disciplinary ideas and project findings.

INTRODUCTION

Over the last 20 years, Cambodia's economy has undergone impressive growth, averaging approximately 7% per annum of Gross Domestic Product (GDP) (World Bank, 2015) and resulting in a drop in the national poverty rate to 20% (World Bank, 2015). Despite these gains, the majority of people remain highly vulnerable to falling back into poverty. Recently the 2015/2016 El Niño event caused widespread crop losses that impacted significantly on incomes and levels of indebtness throughout Cambodia (FAO, UNICEF & WFP, 2016). Even without shocks like this, an income loss of 1200 Cambodian Riel (CR) (US $0.30) per day is enough to double the poverty rate (World Bank 2015). Additionally, while the incomes of some farmers have increased overtime, the average size of the 1.8 million agricultural holdings is 1.6 ha (Kingdom of Cambodia, 2015). Smallholder farmers, who tend to operate under traditional farming systems, struggle to diversify and achieve farm viability and have experienced stagnation of incomes.

Poverty reduction and improved food security remain important agendas for Cambodia (MAFF, 2015; ACIAR, 2017). There is growing recognition of the importance of transdisciplinary research for responding to 'wicked' problems such as these (Lawrence & Despres, 2004; Hadorn et al., 2006). Transdiciplinary research is particularly appropriate for problems that are complex, have multiple problem definitions, lack clear solutions and are trans-sectoral (Lawrence & Despres, 2004). In spite of this recognition, embedding transdisciplinary research firmly into research activities continues to be challenging. Transdisciplinary research does not have a single definition, however, Cundill et al. (2018 p2) define it as "research processes that support mutual learning across disciplinary divides and knowledge domains, with the goal of producing shared knowledge around a common problem" the aim is to develop an "integrated view of a subject that goes beyond the viewpoints of any particular discipline." Transdisciplinary research is far from commonplace, internationally or in Cambodia. There are many challenges to working in transdisciplinary ways, there are difficulties associated with integrating disciplinary and local knowledge (see Ramadier, 2004) as well as pragmatic issues with operationalising collaboration between researchers, civil society, private sector and policymakers (see Cundill et al, 2018). The collaborative aspect of transdisciplinary research is the focus of this paper.

ACIAR's vision is "a world where poverty has been reduced and the livelihoods of many improved through more productive and sustainable agriculture emerging from collaborative international research" (ACIAR, 2018 p6). Collaboration is central to ACIAR's vision and approach that emphasises "enduring research collaborations within the region and globally (that) are among the most effective, innovative and promising science partnerships, underpinning far-sighted policy, community and industry responses to complex challenges" (ibid.). However, there are a number of constraints to effective collaboration between and within programs and projects at a country level, that arguably impacts on the production of practically relevant outcomes to respond to these challenges.

In this paper, the activities of the Soil and Land Management (SLaM) Program in Cambodia are used to reflect on research collaboration. This paper is based on the experience of a social researcher working on two SLaM projects in Cambodia, drawing on transdisciplinary collaboration literature, reflection on project design and implementation and analysis of project documents across programs in Cambodia (not widely available to researchers from other projects). The author would also like to acknowledge that researchers in the SLaM researchers currently collaborate in a range of ways, it is not the purpose of the paper to debate whether collaboration occurs. Rather, to highlight some of the challenges to collaboration as well as opportunities for improved collaboration to enable better integration of disciplinary ideas and project findings for greater impact. The paper explores collaboration at three different levels:

1. Within projects as a way to better integrate the disciplines
2. With local stakeholders, particularly smallholder farmers, to facilitate mutual learning
3. Between projects to consolidate findings

TABLE 1: SLAM PROJECT OBJECTIVES

SMCN 2012/071: Improving water and nutrient management to enable double cropping in the ricegrowing lowlands of Lao PDR and Cambodia	SMCN 2012/075: Management practices for profitable crop–livestock systems for Cambodia and Lao PDR	SMCN 2014/088: Integrated resource management for vegetable production in Lao PDR and Cambodia	SMCN 2016/237: Land suitability assessment and site-specific soil management for Cambodian uplands
Identify water and chemical soil constraints to the adoption of non-rice dry season crops in Lao PDR and Cambodia.	Determine the productivity potential for integrated crop / forage production systems in sandy terrain in southern Laos and Cambodia	**To analyse input supply chains and identify opportunities to improve their functioning and performance to deliver inputs to farmers in a timely and efficient manner**	Introduce new methodologies for soil and land suitability assessment and identify main soil types and landscape patterns in representative upland regions
Develop technologies and practices for improving water and nutrient management and mitigating soil limitations across the lowlands.	Define soil and water management practices in crop / livestock production systems that increase resilience and profitability, allow greater integration, and diversify enterprises	**To analyse livelihoods and socio-economic and socio-cultural factors relevant to the adoption of improved soil and water management strategies and design and implement strategies for improvement.**	Characterise the soil and land constraints to crop production and identify soil management technologies for these regions.
Produce and communicate appropriately packaged technical and financial information, to support the adoption of dry-season cropping	Identify potential models for intensification of crop / livestock production systems on low fertility sands using **a participatory methodology and evaluate the socioeconomic impacts of system changes**	To develop technically sound and economically viable practices for management of structurally unstable and nutrient deficient alluvial soils (Acrisols) and upland soils (Ferrosols)	Provide tools and information that enable stakeholders to identify the main soil types, and their constraints to crop production.
	Extend new knowledge in integrated crop / livestock production systems and increase research capacity among stakeholders	To develop improved management of irrigation in relation to soil-water status and crop requirements in various growth stages to improve crop yield and profitability.	**Expand the knowledge base of soil resources and capability for soil resource management in Cambodia.**

INTEGRATING THE DISCIPLINES – COLLABORATION WITHIN PROJECTS

Researchers are by in large used to and very experienced at working on projects 'together' with people from different disciplines; project proponents are required to develop proposals that engage researchers from different disciplines, and the review process encourages project leaders to include social research in more than a tokenistic way and cross-cutting issues like gender facilitate collaboration between the disciplines. However, despite this, researchers are perhaps less experienced at collaborating in an integrated way where research questions are written in a way that answering them requires consideration of different disciplinary perspectives. This lack of integration often emerges during the proposal writing phase where objectives, research questions and activities are created around disciplinary groups. For example, the objectives of the SLaM Projects are presented in Table 1 (previous page). This highlights that the social sciences (see bolded text), far from being seen as cross-cutting, tend to be included as discrete objectives designed to analyse project context, develop capacity, disseminate findings and assess impact. SMCN 2014/088's objectives three and four appear more problem oriented. However, the disciplinary distinctions become evident in the short-form used in project documents where they are referred to as: Objective 1: Supply Chains, Objective 2: Livelihoods Analysis, Objective 3: Soils and Objective 4: Irrigation.

There are numerous reasons for a lack of integration (Pohl, 2005; Stokols, 2006):

- Different disciplinary worldviews and research 'cultures'
- Limited experience of working in integrated ways
- Simplification of project management
- Research questions that are not problem oriented
- Skepticism regarding the validity of social sciences
- Complexity of projects both in terms of scope and scale

Some researchers do not see the integration as essential to research, but rather a requirement of funding (Pohl 2005). In the case of one SLaM Project, although attempts were made to have an objective that required natural scientists to have ongoing engagement with social scientists, the logic of this was questioned by researchers more familiar with a linear transfer of technology approach (Balconi, Brusoni & Orsenigo, 2010) that involves finding out what works (the natural sciences) before disseminating findings or assessing impacts (the social sciences). Thus, Pohl's comments on integration remain a challenge in some ACIAR projects.

What would encourage and support researchers to work in more collaborative and integrated ways? Proponents of transdisciplinary research argue that there is the need for a strong commitment from researchers to the goals of collaboration, leadership on this, and training of researchers (Klein, 2008). There is a growing body of literature about a diverse range of tools and ways of 'cultivating transdisciplinary capacity' This includes, but is by no means limited to, adaptable heuristics to help researchers visualize and discuss what it means to do transdisciplinary research (Boyd et al, 2015), professional development programs that support researchers to improve their 'transdisciplinary work' (de Nooy-van Tol, 2003) and mentoring and masterclasses for researchers on how to explicitly reflect on their research practice (Lyall & Meagher, 2012). Other studies emphasise the need for sustained collaboration, noting that even if researchers jointly prepare a proposal they may require "several years of collaboration to become acquainted with and develop respect for the other 'culture'" before being able to work in more integrated ways (Pohl 2005). Pressure to produce usable findings is often responded to with a "pragmatic division of labour." Instead, Pohl (2005) and other researchers advocate for sustained, but more "general pressure to rearrange a particular discipline's knowledge so as to make it useful and meaningful." In practice for researchers (such as those in SlaM) this might require transdisciplinary research training for project teams, co-leadership of projects by natural and social scientists and a revised project proposal pro-forma.

PARTICIPATORY INQUIRY – COLLABORATION BETWEEN RESEARCHERS & LOCAL STAKEHOLDERS

Aside from collaborating with other researchers, transdisciplinary research emphasises the need for "close and continuing" collaboration with a wide range of stakeholders (Lawrence & Despres, 2004), drawing on the theory and methodologies of participatory inquiry (e.g., participatory action research, collaborative inquiry and action research). These approaches acknowledge the importance of mutual learning and involve defining research questions and conducting research with diverse stakeholder groups including scientists and community (see Agyris & Schon, 1974 and Reason, 1994). They align with best practice in development that emphasise the importance of locally driven agendas and local ownership over the process (Bolger, 2000; Lopes and Theisohn, 2003).

Community soils focus group discussion, Tang Robang Village, Cambodia

One way that SLaM Projects try to engage and collaborate with stakeholders is by organising them into groups. In Cambodia, farmers, extension providers, private sector, government and other stakeholders are organised into stakeholder forums, coordination committees, farmer groups, networks etcetera. These groups provide a mechanism for showcasing technologies and sharing findings (e.g., through demonstrations, field days, field trips, farmer exchanges, roadshows, presentations, trainings, farmer field notes, social media). These groups can provide a platform for participatory research and basis for establishing working relationships with stakeholders. However, the means for co-creating research questions and knowledge through mutual learning and contributions to the research activities are often limited.

Some researchers undoubtedly find it difficult to imagine how other (non-expert) stakeholders could contribute to framing research questions and participating in the research. There are also a number of practical obstacles. For example, where projects have set out to conduct research trials on farms (with farmers) there have been issues with quality of the data and uncertainty regarding research outcomes due to the unforeseen activities of livestock and people. Consequently, these projects shifted to demonstrations with the 'real' science happening on a research station. Further, there are a raft of challenges to forming groups such as farmer group, producer groups, cooperatives and innovation platforms. Feedback from in-country partners identified that farmers are not interested or motivated to be involved, that extension providers have reported interest but only for the project duration, or that farmers express interest at times but sustained interest is often patchy. At the same time, "there are major hurdles to be overcome to flesh out the rhetoric of partnership into the reality of a working relationship" with local stakeholders (Maxwell and Riddell, 1998, p.267). Culture may be a further complicating factor; as Berkvens (2017 p162) notes "contemporary Cambodian culture is … strongly affected by historical influences" in particular conflicts and successive occuptions. Berkven has developed a contemporary cultural profile for Cambodia; the profile highlights a large power distance, which means people tend to accept that it is normal for people to have unequal power and particular positions in the hierarchy of power (see Hofstede's (1986) cultural dimensions for more information). For collaboration between researchers and local stakeholders this means that researchers tend to be viewed as experts and that this may make it difficult for researchers and local stakeholders, particularly smallholders, to work in integrative ways that require them to question and challenge researchers. It should also be noted that the challenge of participatory inquiry may arise from a blurring of lines between research, development and research for development.

According to Reason (1994), researchers require a "range of skills for participative research" these include personal and interpersonal skills including reflection, self-awareness and facilitation. Other researchers and practitioners argue that fundamentally what matters is attitude (e.g., Chambers and Pettit 2004; James and Hailey 2007) and the ability of organisations and individuals to reflect upon and to change their practice (e.g., Eyben 2006; Pasteur 2006). Chambers and Pettit (2004) describe this as personal agency, awareness and responsibility.

A relatively new requirement of ACIAR project proposals is to articulate a pathway to impact (Vogel, 2012). This activity requires researchers to "describe the logic and mechanism from research outcomes to development impacts for the end-users" and in doing so reflect on how they will work with local stakeholders. However, the utility of this activity to some extent seems to be undermined by a lack of expertise and experience in development theory and practice. The practical steps to improve collaboration between researchers and local stakeholders could include training in participatory inquiry and development theory. Opportunities also exist to partner with non-governmental organisations to gain insight into these approaches.

CONSOLIDATING FINDINGS – CROSS PROJECT COLLABORATION

In addition to the potential benefits of improved collaboration within projects, opportunities exist for better sythesising the work of the SLaM program to consolidate findings about sustainable intensification of agriculture in Cambodia. Investigating ways to improve soil management is an integral part of all four projects as a way to improve productivity/profitability of farming systems. Activities include: identifying soil physical and chemical properties and constraints to crop production; trialing different management approaches; learning about different livelihood factors and contexts that impact on soil management practices; conducting input supply studies to understand the feasibility of different management approaches; conducting value chain studies to understand the markets for different crops; and, designing, developing and delivering tools/trainings/resources to improve soil management practices. Although the findings of individual projects are somewhat site and crop specific, opportunities for lesson sharing across projects still exist. A number of strategies are currently used to foster cross project collaboration such as a requirement that projects identify the relationship between their project and other ACIAR investments during the proposal writing phase, project leaders meetings, invitations to attend annual meetings and to a lesser degree joint forums/activites. However, while this facilitates an exchange of information less work is done to consolidate findings. For example, what's the collective knowledge around soil acidity and its management? At least two projects are looking at lime sources and supply chains, while another is asking the question whether germplasm selection or soil amelioration is the more fruitful approach to alleviating subsoil acidity. All four projects are developing tools and methodologies for training farmers and extension providers, for instance simple tools for visual soil assessment and soil idenfication. Lessons could be generic (e.g. about appropriate training and extension methodologies), or specific (e.g. about the suitability of tools tested/developed).

Across programs researchers are exploring related topics and themes. A key theme of the Livestock Systems Program is "managing intensification of small-scale livestock systems." In Cambodia, the introduction of forages has been a core component of a Livestock Systems project. This has included forage management training, analysis of the socio-economic benefits of growing forage and analysis of the factors that motivate farmers to adopt forages. An updated forage and cultivation technique handbook for smallholders and extension staff is under development. Concurrently, two SLaM Program projects are undertaking work on forages. One project aims to "establish dry season forage production as an intrinsic component of smallholder farming systems" the other "increase resilience of crop and livestock production through improved forage and fodder production and improved use of water and nutrients on sandy toposequences." These projects are working in the same location. This raises questions about the consistency of messaging regarding ways smallholders can improve their livelihoods, and the extent they are building on each others research to achieve the best outcomes for improving intensification of crop-livestock systems in Cambodia.

Multiple barriers to projects and programs working more collaboratively and integrating the findings of their research exist. Researchers are under pressure to publish findings and this can prohibit the timely sharing of information. Project team members are busy on many projects and activities and collaborating may be viewed as time consuming – for instance the sharing of information may require additional work to put it in a more usable form. Often project members move on to new projects and reporting of previous work becomes difficult as they no longer mandated (either in terms of time or resources) to continue working on the former project. There are also practical issues of how you manage budgets, staffing and resources for collaborative activities. Despite these barriers, opportunities exist to strengthen collaboration. For example: sharing of project documents and reports, alignment of project review meetings to facilitate discussion, joint conferences and workshops, development of a repository of training resources, encouraging in-country partners to share insights across projects and support for cross-project and program activities. Most recently ACIAR has commissioned small cross-project activities to facilitate this.

SUMMARY

Collaboration is an integral part of the work of researchers in the SLaM Program in Cambodia, but a number of challenges to collaboration exist. This paper has highlighted some of those challenges while identifying opportunities for strengthening collaboration to better facilitate transdisciplinary research and enable integration of disciplinary ideas to achieve practically relevant outcomes and maximize impact for smallholders in Cambodia. These include: training for project teams on transdisciplinary research, participatory inquiry and development theory; co-leadership of projects by natural and social scientists; revised project proposal pro-forma; partnering with non-governmental organisations; sharing of project documents and reports; joint conferences and workshops; and, development of a repository of training resources. Recently, the SLaM Program has initiated small grants for cross project research activities – this is another way that collaboration can be encouraged.

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Farmers discussing soil texture in Prey Thom Village, Cambodia

Women underpin food crop production, Nepal

ENABLING SMALLHOLDERS TO TACKLE THE CHALLENGES AND OPPORTUNITIES OFFERED BY INTEGRATED CROP MANAGEMENT IN CONTRASTING CULTURAL SETTINGS, IN THE PHILIPPINES AND PACIFIC ISLANDS

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ABSTRACT

Smallholder farmers in the Asia-Pacific region grow diverse vegetables, often in complex, mixed-cropping systems, offering various opportunities for improved livelihoods. However, farmers often respond to pest-and-disease threats with ill-founded use of agrochemicals which may exacerbate such problems. ACIAR-funded projects in the Asia-Pacific region have helped farmers to develop and adopt integrated pest and crop management approaches, drawing on elements of earlier initiatives, including farmer field schools, but emphasizing a flexible approach that takes into account the local social, cultural and economic context of vegetable farming, and the national regulatory and policy environment. Projects have invested in developing relevant problem-solving research capacity and attitudes among public-sector research partners, as well as information resources appropriate for smallholders. Private sector partners have been engaged in technology development and farmer training, becoming key agents of change. Common and contrasting experiences from projects in the Philippines and Fiji are discussed.

INTRODUCTION

Growing various kinds of vegetables, native and exotic, offers smallholders in South-east Asia and the Pacific islands both opportunities to increase their cash income and to improve the nutrition of their families. However, this valuable source of improved livelihoods is often jeopardized by outbreaks of pests, diseases and weeds, which can cause severe losses in quantity and quality to vegetable crops. In an understandable reaction, to try to protect their crops and income, smallholders often respond by spraying their vegetables with pesticides (broadly defined to include insecticides, fungicides, herbicides and related agrochemicals), using whatever products are available through local agricultural input suppliers. These products are often purchased and applied without an accurate diagnosis of the problem and their use is based on an inadequate understanding of their mode of action and possible side effects.

Such incautious use of plant protection products can cause a cascade of problems, sometimes greater than the initial issue that they were supposed to address: by killing beneficial natural enemies, pesticide applications can lead to further pest outbreaks, either of the initial species or of secondary species released from the control provided by natural enemies; pesticides applied without due attention to safety precautions and protective equipment can endanger the health of farmers while failure to respect pre-harvest intervals can leave excessive residues that threaten the health of consumers; and lack of understanding of the environmental effects of agrochemical residues can lead to inadvertent pollution of groundwater and waterways, with further negative impacts on human and environmental health. While these impacts can often be inferred from experiences elsewhere or deduced from researchers' observations, they are rarely directly measured in developing countries, due to weaknesses in the regulatory framework for agrochemical use and the lack of resources for environmental monitoring.

Integrated pest management (IPM) (Barfield and Swisher, 1994) and integrated crop management (ICM) (Meermen et al., 1996) have been proposed by researchers as the most rational approaches for smallholder farmers to use, as a means to reduce their dependence on agrochemicals (Stern et al., 1959; Binns and Nyrop, 1992). These approaches are closely similar in that they seek to deploy crop varieties that are genetically resistant to stresses and combine these with management practices, based on ecological principles, that minimise negative impacts on the crop; they differ mainly in emphasis, with IPM focusing on managing pests, diseases and weeds (especially by enhancing the 'biological control' provided by natural enemies) while ICM emphasizes managing the farm environment to enhance 'crop health'. In principle, there is really no alternative to such 'integrated' approaches, which have even been adopted by pesticide companies to promote the effective use of their products. However, in practice there are a number of characteristics of smallholder farmers' production systems in developing countries that can make these approaches hard to develop and apply (Van Huis and Meerman, 1997).

Perhaps first and foremost, the complexity of smallholder production systems, typically involving growing several varieties and species of crops together, can be seen as both a strength and a challenge from a crop management perspective. The diversity of genotypes and species of crops will reduce the tendency of a pest or disease to spread through the smallholder farm – as compared with the monocrop of a single variety, typical of intensive commercial horticulture in industrialised countries, which facilitates epidemic spread. Moreover, the diversity of crops and products from a smallholder's farm will help to make his or her livelihood more 'resilient' in the face of pest-and-disease outbreaks, unfavourable weather or changing economic conditions: unfavourable conditions are unlikely to affect all components of a cropping system simultaneously so, even if one crop or variety is badly affected, the smallholder will usually have 'something else' to harvest and consume or sell. On the other hand, the diversity of crops produced on smallholders' farms greatly multiplies the knowledge base needed to manage the farm successfully (in terms of recognizing the pests and diseases associated with each crop and understanding each crop's requirements) and the complexity of ecological interactions potentially increases exponentially with the number of crop species, pests and natural enemies (and the interactions between trophic levels) involved.

The benchmark for the adoption of IPM by smallholders in developing countries was established by the Food and Agriculture Organization of the United Nations (FAO) in the late 1980s, when the 'Farmer Field School' (FFS) was developed and promoted as an extension approach to help farmers in South-East Asia to tackle problems associated with excessive insecticide use in rice (Indonesian National IPM Program, 1993; Kenmore et al., 1995; Useem et al., 1992). This approach, using adult education principles and emphasizing 'learning-by-doing' (especially farmer experimentation), was seen as an alternative to the overly prescriptive and 'top down' extension approach typical of the Green Revolution in South Asia (Ooi, 1996). The FFS and IPM in general was subsequently propagated during the 1990s to tackle similar problems of smallholder rice crops in other countries and eventually a much wider range of crops and issues around the world (Kenmore, 1991). Different versions (and advocates) of the FFS-based IPM model subsequently emphasized different aspects of the approach, such as the value of farmers' indigenous knowledge or of farmers' own research (as compared with conventional, formal or institutional research) (Rolling and Van der Fliert, 1994; Scoones and Thompson, 1994). There was also an intense debate about the cost-effectiveness of the FFS-based approach, leading FAO and others to experiment with variants on the basic model, for instance seeking to generate income within each field school or to use a 'rolling fund' to finance repeated cycles of field schools.

Ironically perhaps, given the origins of the FFS approach, the FAO-sanctioned core of the FFS-based IPM 'movement', became quite prescriptive, developing its own lexicon of terms and defining a number of non-negotiable features of its particular brand of FFS (e.g. Bentley, 2009). It could be argued that, while useful for advocacy purposes, these prescriptions have made FFS-based IPM harder to adapt to the needs of smallholders growing different crops in various social and economic contexts.

Over the past ten years (including the period of the authors' engagement with the agency), ACIAR has funded a considerable number of projects that explicitly focused on IPM or ICM as the preferred means to tackle smallholders' production issues or that included these approaches as a major component of project research. Some of these projects focused on 'classic' insecticide-overuse issues (such as projects on squash in Tonga and Brassicas in Fiji and Samoa) whereas others looked more generally at managing pest- and disease-related problems in an integrated manner (such as projects on cocoa pod borer and phytophthora pod rot of cocoa in Papua New Guinea and Indonesia, or pests and diseases of citrus in Pakistan or of mangoes in the Philippines). Many of these projects used some form of FFS as at least a significant component of the project's extension strategy – and some used FAO-trained trainers to initiate the learning cycle – although probably in all cases, the methodology differed from the strict FAO prescription. Most obviously, the ACIAR project field schools typically did not involve weekly meetings throughout the entire crop cycle and were thus less demanding on farmers' time, reflecting the belief of many of ACIAR's research partners that smallholders are 'time-poor' and that the time needed to learn about, develop and apply ICM strategies can be a major limitation on the adoption

Resources provided via smartphones can supplement the limited conventional information available to IPM trainers and farmers.

" Growing various kinds of vegetables, native and exotic, offers smallholders in South-east Asia and the Pacific islands both opportunities to increase their cash income and to improve the nutrition of their families. "

of this approach by smallholders. The ACIAR project field schools also differed in that they used significant information resources, conventional and novel, that were generated and supported externally, rather than from within the FFS (which is an important principle in the FAO model). These information resources, on paper and online, were regarded as important to the success of the ACIAR projects in providing a sound foundation of knowledge for ICM – and specific examples are discussed further below.

Finally, the ACIAR project field schools differ very obviously from the FAO model in their explicit dependence on formal, institutional research conducted by local universities or government research organizations, to provide the knowledge base for ICM implementation. To some extent, this reflects pragmatic and operational differences, with ACIAR projects being targeted 'earlier' in the research-to-implementation continuum, at a stage where basic understanding of problems is gained and new technologies generated and tested at pilot scale, whereas FAO IPM projects have typically been targeted at large-scale adoption by farmers, in situations where the root cause of pest problems (i.e. over-use of pesticides) was considered to be self-evident. However, the differences also perhaps reflect a philosophical commitment by ACIAR to the value of formal research in generating innovations and helping smallholder farmers to adapt and apply them in an iterative cycle of interactions between researchers and smallholders.

ACIAR'S EXPERIENCE OF ICM RESEARCH & ADOPTION

In summing up the experience of over a decade of ACIAR investment in IPM and ICM research in the Asia-Pacific region, some key elements have emerged:

- Social science research and the insights it can provide into the social and cultural context of farming is vital to the successful adoption of ICM. This includes gaining an understanding of and sensitivity towards traditional gender roles in farming communities and the influence of religion and other traditional beliefs and power structures.
- Similarly, an understanding of the broader economic context of farming in the livelihood strategies of smallholders is indispensable. This need not imply research that is sophisticated in terms of economic theory but needs to provide insights that are broader than the simple 'profitability' of crop management strategies. Often, ICM strategies that appear at first sight to be highly profitable in terms of increased yield or reduced costs, may not be adoptable when broader considerations of risk or perceptions of food security are taken into account.
- The regulatory and policy environment, enabling or obstructive, plays a key role in ICM adoption, including the possibility of a considerable gap existing between the legislative and regulatory framework and its practical implementation on the ground. Many developing countries in the Asia-Pacific region have a framework for registering agro-chemicals, intended to protect human and environmental health, which is based on European, American or Australian models; however, many of ACIAR's partner countries lack the resources to operate the provisions of legislation and monitor compliance. In the absence of an effective regulatory framework, low-quality products tend to enter the market through informal channels, distorting both the market incentives and farmers' perceptions of effectiveness, as well as consumers' perceptions of value. On the more positive side, there may be opportunities for research results and project researchers to influence policy and help to contribute to a more positive policy environment.
- Specific provision may need to be made to ensure that flexible information resources, tailored to the evolving needs of smallholders, are available. Given the weak and under-resourced state of government-provided extension services – and the absence of private-sector alternatives – farmers need information to support decisions at all stages of the crop management cycle, from selecting crops and varieties, diagnosing pest, disease and other production problems, through decision-support among management options, to information relating to options for value-addition and marketing. The use of smart phones and the internet is widening but these technologies are not universally available in rural communities and many smallholders, even when they can afford access, are not fully internet-literate. Thus a range of resources, on paper and online, may be needed, that are pitched at the appropriate level of sophistication and that can be updated to take account of emerging pest and disease problems, as well as changing regulations and innovations in plant protection and production technologies.
- In the absence of private-sector product research-and-development that is specifically tailored to the needs and interests of smallholder farmers, formal publicly funded research is needed to support ICM, currently and for the foreseeable future. Conventional educational systems in most partner countries have not generated a capacity for, or great interest in, agricultural innovation and problem-solving research. Thus, ACIAR-funded projects have often found it necessary to engage deeply in the tertiary education system, to promote interest in applied research and catalyse the establishment of novel partnerships that can support multi-disciplinary research-for-development.
- Finally, a flexible approach to engagement with the private sector is needed, depending on attitudes and market forces prevailing in a particular country and situation. In South-east Asian countries, the smallholder horticulture sector may be of sufficient economic significance to provide a valuable market even for larger input suppliers: ACIAR-funded projects in the Philippines, for instance, have engaged successfully, especially with seed companies, to promote the adoption of ICM technologies that 'work' for both smallholders and suppliers. Elsewhere, as in the Pacific islands, smallholder markets may be too small to provide major input suppliers with an economic incentive to develop, register and distribute well-adapted crop varieties or plant protection technologies suitable for the use of smallholder horticulturists. It may nevertheless be possible, as in the Fiji case discussed below, to find ways for researchers to engage with local input companies to find solutions that are mutually beneficial, for commercial suppliers and smallholders.

In the next sections, we look at how these principles have worked out in practice, to affect the development and adoption of ICM approaches by researchers and vegetable growers in two contrasting countries, the Philippines and Fiji.

PHILIPPINES

The issues

Smallholder farmers in the Philippines have a history of heavy use of insecticides and fertiliser – driven by both commercial interests and conventional Green Revolution thinking. Indeed, overuse of pesticides on rice in the Philippines first sparked the interest in radically different approaches that embraced ecological principles and integrated them into crop management (Kenmore et al. 1984)

However, by the time that the current ACIAR projects were being developed, an ill-thought-out 'over-reaction' by the government, made the pursuit of organic agriculture (rather than ICM) the official policy (see Regulatory

In the Philippines, evaluation sites established by a seed company provide an ideal setting for research-farmer engagement.

"ACIAR-funded projects in the Philippines, for instance, have engaged successfully, especially with seed companies, to promote the adoption of ICM technologies that 'work' for both smallholders and suppliers."

and policy environment, below). This had the perverse outcome of making the development and promotion of ICM more difficult: publicly-funded researchers in the department of agriculture and universities were not allowed to conduct trials involving pesticides, divorcing them from the everyday reality of smallholders who were, in practice, still heavily dependent on them and excluding the possibility of researching incremental, step-wise improvements. Selective and safer pesticides (and information on how to use them) were not generally available, either through private sector suppliers or official extension services.

Meanwhile, a vague belief that 'natural' products were somehow safer than synthetic ones led to a proliferation – in official extension advice and on farms – of various 'folk remedies'. At best these were unregulated and of dubious effectiveness and at worst downright dangerous, especially from a food safety perspective. Fermented plant and fruit juices, including cultured rice are commonly recommended and used. Of greatest food safety concern is the use of FAA (fermented amino acid) products which are fermentations of fish, snail or meat products that are sprayed on food crops (Anon 2006).

Monitoring of farmers' fields revealed combinations of invertebrate pests and a range of diseases. Most commonly these were soil-borne fungal diseases but also included a range of bacterial diseases, a small number of viral diseases and some nutrient disorders. Farmers had difficulty identifying the causes of plant damage and hence were not generally using appropriate cultural practices to reduce cross contamination or to support the growth of healthy plants (i.e. adequate water and nutrition). Farmers often obtained advice from local farm suppliers, based on their own descriptions of problems, which resulted in application of inappropriate pesticides and fungicides.

The social & economic context

The smallholder farmers in the central southern Philippines who were engaged in ACIAR's ICM projects varied considerably in their educational, family and economic situation. In one survey, all had Elementary schooling, half had Secondary schooling and approximately 10% had received College education, while a small number had obtained degrees. They were all married; approximately half had 1-3 children, a quarter had 4-6 children and 5% had more than 7 children. They all considered themselves primarily farmers, cultivating between 1.5 and 2 ha of land that approximately half owned individually, while another 40% were share tenants and 10% leased their land. They reported an annual farm income of approximately P25,000 (c. AUD$800). All grew two or more kinds of vegetables; 50% also grew rice and a quarter grew fruits. About 20% reported other off-farm income. On average their farms were 9 km from their local vegetable market.

Vegetable production is strongly market-oriented and price-conscious. However, consumers currently have little awareness of pesticide risks (at least in regional markets) and are generally unwilling to pay more for better quality (including improved food safety).

The regulatory & policy environment

With the introduction of the Organic Act of 2010, agricultural researchers and extension officers focused on organic options rather than including agrochemical options in crop protection recommendations. There is a strong regulatory framework for registering pesticides however there is poor enforcement. There are many low-cost and potentially low-quality pesticides available, many illegally imported and improperly labelled. There are some more selective and ecologically rational products available but there is inadequate information on what is available. Although there is a rating based on human toxicity, there is nothing to indicate their value in IPM. For example, the pyrethroids are rated as 'green' (based on their low mammalian toxicity), even though their broadly negative impact on natural enemies tends to make them unsuitable for inclusion in IPM programs.

At a local level, smallholders shared a common misunderstanding that formulated pesticides are all uniformly 'bad'. On the other hand, researchers developing biorational products, such as the nuclear polyhedrosis virus for control of Spodoptera, are obliged to provide data for registration equivalent to other (chemical) pesticides. Yet there seems to be no regulation of, or concern relating to the potential risks associated with, the home-brewed pesticides.

There is some capacity to test for insecticide residues but this is confined to organo-phosphates, organo-chlorines and synthetic pyrethroids and does not include new active ingredients or fungicides.

Information resources & research support

The Philippine state is a strong supporter of agricultural research, particularly through the University of Philippines Los Baños but there is now an additional focus on increasing the capacity of regional universities. Across the university system, there is a tendency towards traditional academic attitudes, with relatively little value accorded to applied, problem-solving research. Projects with long-term commitment (from ACIAR and research partners) have had some success in awakening this latent research capacity and, usually by forging novel partnerships, have generated capacity and enthusiasm for applied, multi-disciplinary ICM research. These new ideas and approaches have been taken up with enthusiasm by some partners, especially those who have been involved in multiple project phases and whose engagement has evolved over time. However, behaviours questioning conventional wisdom, critical thinking and problem-solving were more alien and have proven more of a challenge for the staff of the smaller, mainly teaching universities who have had very little exposure to research. Participation in research projects is also difficult for staff in that they all have full teaching loads so have little time for field work, critical evaluation of data and reflection.

Farmers have only very limited sources of information and this is largely in the form of on-paper fact sheets. There is very limited information available within the Philippines on pesticides, modes of action, relative toxicity, pros and cons, or their fit within an integrated pest management strategy. There are huge opportunities for using digital technology which will become a more flexible and effective platform as more farmers purchase smart phones. Local advisors are particularly keen for information to support them and their farmers.

Engagement with the private sector

A number of seed companies are actively engaged in the Philippines with training farmers. East-West Seeds, have a commercial interest in promoting ICM as the best context for promoting the wider use and commercial success of their improved crop varieties. East-West Seeds has engaged enthusiastically with the ACIAR vegetable ICM projects, contributing to the research, and incorporating research results into their training of farmers.

These companies have become the most effective agents of ICM adoption by smallholders and will continue to play this role in the Philippines.

The way ahead

A new ACIAR-funded project has recently been launched, led by a private sector company in Australia – albeit one with strong ties to public research sector and continuing to draw heavily on this research base.

With the change of government in the Philippines, the new ACIAR vegetable project is actively engaging with regulators and aims to influence the regulatory environment, to produce an 'enabling policy environment' for wider adoption of ICM.

The project will continue to build the capacity of the regional university system to conduct relevant critical research in direct support of ICM.

"The smallholder farmers in the central southern Philippines who were engaged in ACIAR's ICM projects varied considerably in their educational, family and economic situation."

FIJI

The issues

In the Sigatoka valley, the principal production area for non-traditional vegetable crops in Fiji, most farms are small (75% of them having an area of less than 2 ha) and 40% of farmers report incomes less than the national average. In recent farmer surveys, pests and diseases were considered the greatest threats to the production of the key vegetable crops (tomato, head cabbage, Chinese cabbage and aubergine) and high levels of broad-spectrum synthetic pesticide are used. Despite the poor quality of soils in the area (documented by researchers), farmers did not consider this a major constraint to production – perhaps because they typically use large amounts of synthetic fertilizer, and are not aware of the broader problems associated with overall poor soil health.

Government extension services are weak, and the existing pesticide regulatory system has been in place since the 1970s. Consequently, poor quality and often unsuitable pesticides are imported and distributed, and inappropriate advice is provided by retailers, who are typically ignorant of the dangers that this presents. The over-use of insecticides is particularly acute in Brassica crops where, in their attempt to control a complex of destructive caterpillar pests, farmers typically spray crops at least once a week, often with a mixture of compounds. This has devastated natural enemy populations, leading to outbreaks of secondary pests and high levels of insecticide resistance in the key pest, the diamondback moth (*Plutella xylostella*) (*Atumurirava and Furlong, 2011*). Tomato crops in particular suffer from a wide range of fungal and bacterial diseases. These are poorly understood by farmers and their access to tropically adapted, disease-resistant varieties are limited (see overleaf).

The social & economic context

In Fiji, there is a long history of horticultural traditional knowledge, but this is focused on a limited number of traditional crops (especially taro) in subsistence farming systems; these rely heavily on slash-and-burn agriculture (with long 'bush fallows'), rather than crop rotation, to replenish soils and reduce the impacts of pests and diseases. Consequently, there are significant gaps when traditional knowledge is applied to commercially oriented, intensive systems cultivating non-traditional vegetable crops and the new problems (e.g. exotic pests and diseases, depletion of soil fertility) that they present. The traditional land tenure system gives little or no security to individual farmers and discourages investment in fixed assets, including soil fertility, and farmers rely almost entirely on government schemes for innovation and responses to emerging production and management problems. Thus, farmer education programs often have little to build upon and need to start from first principles.

The regulatory & policy environment

The regulatory framework, which is based on the Australian system, is cumbersome and now under-resourced. For example, a proposal to update pesticide legislation has been before parliament for almost a decade. Such bureaucratic impasses, while failing to protect public health and the environment, also impede agricultural development as the testing and registering of plant protection products and new crop varieties is difficult. Nevertheless, ACIAR projects have had some success in engaging with government agencies and regulators, allowing new vegetable varieties and plant protection products (see below) to be registered and disseminated. For example, the Ministry of Agriculture has recently released and promoted two tomato varieties ('Melrose' (CLN 3150A-5), tolerant to tomato yellow leaf curl and tomato mosaic virus, and 'Rio Gold' (CLN 2071D), tolerant to bacterial wilt and fusarium wilt [race 1]). Approval was based on long-term field trials, supported by ACIAR projects, that tested the field performance (pest and disease tolerance and yield), quality and marketability of eleven candidate lines provided by the World Vegetable Centre (a partner in the project).

Information resources & research support

Public service research and extension structures in Fiji (and elsewhere in the Pacific islands) have small numbers of staff and find it difficult to build and sustain capacity, with many qualified staff choosing to migrate, especially after post-graduate training overseas.

Capacities at the national and regional universities in Fiji and the Pacific are similarly constrained, exacerbating the limitations of government research and extension organisations. Through several recent projects, ACIAR's long-term strategy has been to build research capacity that is based on understanding ecological principles and can be applied to new crops and emergent pest-and-diseases as needs and opportunities emerge. To this end the long-established John Allwright Fellowship scheme has been supplemented by the ACIAR-University of the South Pacific scholarship scheme which formally affiliates post-graduate students with current ACIAR projects; this provides the students with access to additional supervision and expertise while simultaneously developing the research capacity of local academics – and helping to infect both students and university supervisors with an enthusiasm for applied, problem-solving research.

In recent years a growing body of hard copy, online and 'app'-based information resources has been produced. Notably, fact sheets providing information for 100 key pest and disease problems in Solomon Islands in a previous ACIAR project have been used as the basis for a free mobile app for the region. This resource, Pacific Pests and Pathogens, was updated in 2018, and now contains 350 fact sheets that can be also be accessed on line, enabling electronic and hard copies to be easily accessed and shared. A companion app, that enables the sharing of plant protection information, including informal diagnosis of disorders, has also been launched.

These resources provide fundamental support to a regional program of 'plant health clinics' that is training local extension staff as 'plant doctors' who can provide diagnostic and management advice directly to farmers attending the clinics. Information sharing amongst stakeholders (local plant protection research and extension personnel, farmers and experts in Australia) is also promoted by a locally run 'WhatsApp' group that is being developed to provide rapid responses to individual queries and real-time support for plant health clinics.

Engagement with the private sector

Across the Pacific, markets are very small, providing little incentive for the commercial testing of crop varieties for local environments or the registration of selective plant protection products. A notable success has been the partnership between an ACIAR project, FAO and a local retailer in Fiji to test, register, import and commercially market an effective, inexpensive formulation of Bacillus thuringiensis targeting caterpillar pests of Brassica crops. The product, locally packaged in small quantities and labelled in English, Fijian and Hindi, was launched in Fiji in 2014; it is sold with information on appropriate application methods and recommendations on how it can be used as part of an insecticide resistance management (IRM) strategy. Since its release, sales have been high with concomitant reductions in the sales of hazardous broad-spectrum insecticides for Brassica pests. Further, adoption of the IRM strategy has eliminated the high levels of resistance to several insecticides previously documented for diamondback moth and has allowed their natural enemies to build up again in farmers' fields.

The way ahead

The latest in the series of ICM projects in the Pacific islands has recently been launched, further building on the regional 'peer-network' of IPM/ICM practitioners established over the last decade or more. The Plant Health Department of the Pacific Community (SPC) serves as an informal hub for the network, with networking facilitated by both face-to-face project meetings and frequent on-line communication, partly through the app mentioned above.

Additional countries will roll out plant clinics as the 'front line' of plant protection diagnostics for smallholders in rural areas and the ACIAR project will continue to develop the resources needed to support them.

In the new project, more focus will be placed on the active deployment of biological control, to complement the conservation of natural enemies inherent in the 'pesticide reduction' approach to IPM (which will continue).
The Pacific islands have always been vulnerable to invasive pests and in the past there have been various international efforts to support classical biological control in the region. This latest initiative supported by ACIAR responds both to the emergence of new pest problems – such as the 'Guam strain' of the Coconut rhinoceros beetle – and to the perception that biological control agents previously released may have disappeared through 'local extinction' (which is to be expected in the population dynamics of pests and natural enemies in small island environments) or may have become less effective due to changing conditions.

DISCUSSION: PROSPECTS FOR SMALLHOLDER ADOPTION OF ICM

Some of the common trends and emerging opportunities for the adoption of ICM by smallholders are already evident in the 'case studies' above. With growing prosperity across the Asia-Pacific region, consumers are likely to become more sophisticated in their understanding of food quality and food safety issues, providing a stronger incentive to smallholders to adopt ICM

Farmer field school' in Fiji starts with explaining the basic principles of crop ecology

> "...some Pacific island producers are already responding to the marketing opportunity for 'clean green' fruit and vegetables from their 'pristine' environment, while some countries have moved to ban synthetic agrochemicals."

approaches. However, if ICM and biological control are to become the prevalent approach to crop protection across the region, governments will need to comprehensively update the regulatory framework for crop protection, food safety and the environment, in order to provide a more positive policy environment. The growing network of researchers, empowered by their understanding of crop ecology and their enthusiasm for problem-solving research, will be key agents of change in this area.

The experience of numerous ACIAR projects, across a range of geographies, has demonstrated the value of a flexible, non-doctrinaire approach to ICM that encourages researchers to engage directly with smallholder farmers and a range of farmer intermediaries, including private sector actors (and especially suppliers of seeds and other inputs), to test, adapt and adopt new ideas in an incremental and iterative cycle of innovation. Internet-based technologies, while not providing a 'silver bullet' to solve the problem of information support, will surely make a significant contribution to making relevant, accurate information widely available to smallholders in a form that can respond quickly to their evolving needs.

One big question in this field relates to the future of organic production. Formal organic production (i.e. based on third-party certification) has not previously been emphasized by ACIAR. Partly this has been due to the lack of a strong research base in Australia – which is a pre-requisite for ACIAR's partnership model. More importantly, practical experience (and some formal research) suggests that the reward of higher prices does not usually compensate smallholder farmers sufficiently for the extra cost of third-party registration, as well as the lower yields and extra labour typically associated with organic production. However, there does appear to be a growing demand for organic products among increasingly prosperous and health-conscious consumers in Asia. Meanwhile, some Pacific island producers are already responding to the marketing opportunity for 'clean green' fruit and vegetables from their 'pristine' environment, while some countries have moved to ban synthetic agrochemicals, either specifically to protect freshwater 'lenses' beneath the islands (that provide safe drinking water but are liable to pollution by agrochemicals) or as a step to declaring entire islands as 'pesticide free'. If these trends translate into specific demands from ACIAR partners for research to support a transition to organic agriculture, this should not involve just the substitution of plant protection products already known to be dangerous by others of unknown value. Rather, research offers the opportunity to 're-design' organic systems, 'from the ground up', based on crop health principles. If this approach is followed, then ACIAR's model of researcher-smallholder engagement, developed in the context of ICM projects, should prove well adapted to this new opportunity.

Looking a bit further ahead, managing the crop 'microbiome' – the community of micro-organisms associated with the rhizosphere, leaf surface and interior of crop plants (endophytes) – may offer a 'game-changing' opportunity to increase the productivity and sustainability of cropping systems, especially perhaps those of smallholders. Although this idea has been around for a while and is based on similar agro-ecological principles to those underpinning ICM, recent advances in in DNA/RNA technology now bring within the reach of researchers and farmers the possibility of understanding and managing the microbial ecology of crops, without a prohibitive price tag. A limited version of this approach, based only on managing cropping systems for 'soil health' has already shown success in practice, in the context of ACIAR projects, for managing soil-borne pests and diseases of taro in Fiji and, on a larger scale, addressing the threat of Panama disease of banana (caused by Fusarium oxysporum f. sp. cubense), in the Philippines and Australia. As well as broadening this approach to provide a more comprehensive solution to Panama disease and to tackle additional diseases in banana, the managing-the-microbiome approach should also be readily applicable to managing other Fusarium species and then other pests and diseases in vegetables. Again, this should not be seen as a 'silver bullet' that makes other approaches redundant, but rather as a new extension of ICM principles that could radically strengthen this approach to crop protection in complex smallholder systems – and one that will depend on ACIAR-style partnerships between researchers, farmers and private sector intermediaries for its development and propagation.

In conclusion, it is perhaps self-evident that the development and deployment of ICM and 'agroecology'-based approaches in general will be indispensable in the international effort to help smallholder farmers adapt to the plant protection issues associated with the overarching challenge of our times, namely climate change.

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PRODUCING FOOD WHILE PROTECTING THE ENVIRONMENT: INTER-DISCIPLINARY RESEARCH METHODS FOR INTERNATIONAL RESEARCH ON CONSERVATION AGRICULTURE BASED SUSTAINABLE INTENSIFICATION (CASI)

Agricultural Science Special Issue: ACIAR at Work: Interdisciplinary Research into Smallholder Farming Systems. Combined Volumes 30(2) and 31(1): 2019. Eds: J M Dixon and S G Coffey

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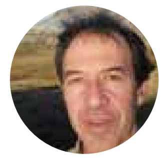

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Dr Eric Huttner started his career in plant molecular genetics working in public research institute, INRA, in France. In Australia since 1990, he has worked for more than 20 years in a range of private companies, including founding a start-up plant genetic analysis service company. He has also been involved in managing public-private research initiatives in both Australia and France. Eric was a founding partner and director of Australia's Cooperative Research Centre for Plant Science and a member of the Australian Biotechnology Advisory Council. Since 2012 he is the Research Program Manager for Crops at ACIAR. He is graduate of France's leading agricultural science school, Institut National Agronomique (AgroParisTech) and was a postdoctoral fellow at the Chinese Academy of Science in 1987.

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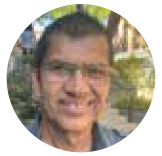
Dr Isaiah Nyagumbo is a Regional Cropping Systems Agronomist based at CIMMYT's Southern Africa Regional Office in Harare, Zimbabwe. Isaiah has been involved in CA, water harvesting and soil conservation research initiatives and one of the pioneers of CA work since the 1990s. Isaiah currently led the agronomy component of the regional program 'Sustainable Intensification of Maize-Legume Systems in Eastern and Southern Africa (SIMLESA) implemented between 2010 and 2019. Parallel to SIMLESA, Isaiah also led the agronomy component of another ACIAR funded project implemented in Zimbabwe 'Integrating crop and livestock production for improved food security and livelihoods in rural Zimbabwe" implemented between 2012 and 2017. Isaiah has contributed to capacity building of farmers and professionals in Southern Africa through field research, training and mentoring of students in regional universities. Isaiah has also authored and contributed to regional research publications focussing mainly on CA, agricultural water management, water harvesting and technology dissemination. His most recent publications focus on productivity of CA systems in Malawi and Mozambique, timeliness advantages of mechanized CA as well as efforts to control prolific termites in CA.



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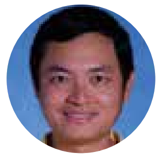

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"Looking at #SIMLESA's evidence, we can say that **#conservationagriculture** works for our farmers"

Josefa Leonel Correia Sacko
Commissioner Rural Economy & Agriculture of the African Union
https://t.co/iLHhnp0Kl9

ABSTRACT

The successful increase in global food supply per capita over the past half-century has resulted in land degradation, depletion of aquifers and loss of biodiversity in many cases. Food security and natural resource management can be improved simultaneously by Conservation Agriculture based Sustainable Intensification (CASI). International research partnerships focused on conservation agriculture and CASI in Asia, Africa and the Middle East supported by ACIAR since the 1990s raised yields and improved natural resource management. The authors discuss the multidisciplinary and interdisciplinary methods used for scoping, research and partnership design, field research, investigation of markets and policies, and scaling, including specific adaptations for CASI. They identify ten areas for further development of research methods associated with CASI, notably: systems research; weed management; climate smart agriculture; decision-making; social capital and institutions; scaling; targeting; policy; food systems; and (regional) spillover management.

CONTEXT AND CURRENT CHALLENGES

The approach of the Australian Centre for International Agricultural Research (ACIAR) to research supports partnership and systems methods for sustainable productivity improvements for poverty and hunger reduction and economic growth which contributes to the achievement of the Sustainable Development Goals. Over the past 50 years the massive surge in food production to feed the burgeoning global population and avert famines has resulted in substantial damage to the environment, notably depleted aquifers, degradation of natural resources and reduced resilience (Cribb 2016).

Since the 1990's ACIAR-supported international research partnerships have adapted and demonstrated conservation agriculture practices, also known as Zero-till (ZT) or No-till (NT), in Asia, Africa and the Middle East. The three well-known core principles of conservation agriculture are: minimal soil disturbance, i.e., reduced or zero tillage; maintenance of a permanent soil cover; and diversification of crops through rotation or intercropping -- with due regard to improved farm profit or livelihoods (Dixon 2003, Pannell et al. 2014). Sometimes, precision agriculture is considered a supplementary principle. In many smallholder and large scale commercial farming systems, conservation agriculture created opportunities for early planting. It also resulted in substantial benefits, including: increased land, labour and water productivities, improved soil fertility, reduced soil erosion, strengthened system resilience and increased farm household net incomes.

Building on these experiences, further ACIAR partnerships initiated during 2010-2019 investigated Conservation Agriculture based Sustainable Intensification (CASI) (see Figure 1). which embodies strengths of both conservation agriculture and sustainable intensification. The latter emphasises concurrent improvements of agricultural productivity and environmental outcomes (Godfray et al. 2010). Thus, CASI incorporates the intensification practices, such as improved cultivars, nutrient, weed and pest management, which are sometimes considered complements to the basic principles of conservation agriculture (Thierfelder et al. 2018). Naturally, CASI research should be targeted to suitable farming systems and market and policy environments where prospective impacts, in terms of productivity, livelihoods and resource improvements, are good. One survey of sustainable intensification in 57 countries found 12.6 M farms applying eight broad types of sustainable intensification, notably including conservation agriculture practices (Pretty et al. 2006). Drawing on technological and institutional innovations from both approaches, CASI identifies sub-sets of potentially transformative innovations tailored to particular types of farmers. While individual CASI innovations, such as zero-tillage, can provide significant benefits (Loss et al. 2014), the greatest adoption rates and transformative results follow from a systems approach with selected combinations of synergistic innovations (Lal 2015, FAO 2016, Kirkegaard 2019). In the context of policy dialogues, the concept of CASI resonates with both the food production/intensification and the environment/sustainability narratives of many Governments and regional and international development organizations.

In this paper, CASI systems research approaches and methods are discussed, based on the experiences of ACIAR partnerships in a variety of farming systems and regions (key features summarized in Annex Table 1). For instance, CASI was successfully applied in two globally-important food bowls: the African smallholder maize-legume farming system by the Sustainable Intensification of Maize-Legume Cropping Systems for Improved Food Security in Eastern and Southern Africa Program (SIMLESA; Keating et al. 2018) and the South Asian rice-wheat farming system by the Sustainable and Resilient Farming System Intensification Project (SRFSI; Reeves et al. 2018). In the former, CASI innovations were adapted to local farmers' needs and adopted by an estimated 484,000 farm households across 8 countries, with benefits for food security, household income (26-137% extra net income from maize) and reduced soil erosion (34-65%), alongside the scientific knowledge, new modelling tools and National Agricultural Research System (NARS) capacity which were produced (SIMLESA 2019). The SRFSI project demonstrated resilient CASI-based irrigated rice-wheat farming systems with improved water use efficiency, returns to family labour and food and nutrition security. The Value Chain and Policy Interventions to Accelerate Adoption of Happy Seeder Zero Tillage in Rice-Wheat Farming Systems across the Gangetic Plains Project (Happy Seeder Policy) focused on value chain analysis and policy dialogue in support of CASI adoption in India and Bangladesh, with the immediate purpose of reducing rice straw burning which contributed to the dangerous levels of air pollution in Delhi and other cities.

The CASI approach has also been adapted for dryland wheat systems in the Middle East by the project Development of Conservation Cropping Systems in the Drylands of Northern Iraq (referred to in this paper as Conservation Cropping; Loss et al. 2014) with major uptake. In the dryland cereal-livestock farming systems in North Africa the project Adapting Conservation Agriculture for Rapid Adoption by Smallholder Farmers in North Africa (CANA) report strong demand for CASI from farmers and up to 58% increased net income in Morocco (El Gharras et al. 2017). CASI is also being tested in rice based systems in south-east Asia by the Sustainable Intensification and Diversification in the lowland rice system in NW Cambodia Project (CamSID) in rice based systems in Cambodia (Tan et al. 2019). Various other ACIAR partnerships have tested CASI practices in other contexts, for example crop-livestock integration, soil management and water management.

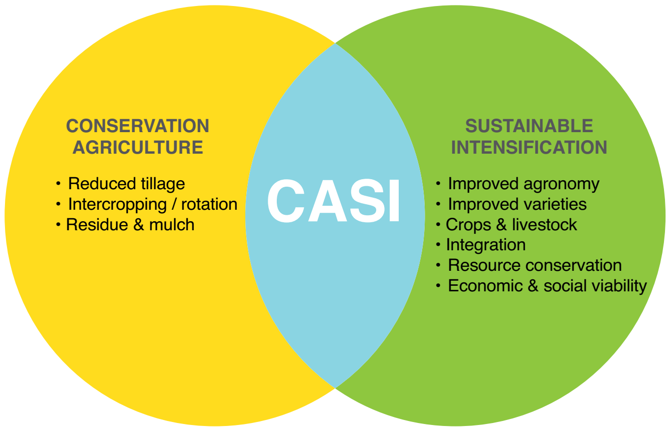

Figure 1: Conservation agriculture based sustainable intensification (CASI) practices (CIMMYT (2019))

There are major CASI research questions at field, farm, landscape and national levels. In 'Save and Grow in Practice' (FAO 2016) the authors developed ten national level recommendations (substantive research questions are associated with each recommendation) for the transition to sustainable intensification, as follows: promote CASI in structural transformation; promote policies that facilitate farmer adoption of CASI; increase investment in agriculture; establish and protect farmers' rights to natural resources; promote more efficient value chains; increase support to agricultural research and development; promote technological innovation in CASI; improve communication with farmers and help build their capacities; strengthen seed systems; and work with international organizations, instruments and mechanisms. Action on these overarching policy actions and associated research questions is critical if CASI is to be successfully adapted and adopted with the timeliness needed to address the imperatives of enhanced productivity, profitability and ecosystem health, in the pursuit of food and nutrition security.

From a science perspective, Giller et al. (2011) proposed a broad research agenda for smallholder conservation agriculture in Africa, noting the overlap with the generic challenges for agricultural development. Field level research questions related to planting dates, land preparation practices (which links to erosion control practices), soil organic carbon, plant density and row spacing, weed management, choice of legumes and complementary inputs e.g., fertilizer. At farm and regional levels, questions included suitable zero-tillage machinery, allocation of labour (which links to returns to labour), crop residues and feed sources, markets, agricultural services and knowledge management. The Nebraska Declaration on conservation agriculture (CGIAR 2013) also lists a number of priority research topics, including management options, broadening the range of agronomic practices that achieve conservation agriculture goals and incentives for conservation agriculture adoption in sub-Saharan and South Asia. Site-specific adaptive research will be important. Following the spirit of the Declaration, the evaluation of CASI innovations could include selected whole farm and landscape metrics e.g., resource use efficiencies (notably water and energy), environmental health, resilience to climate and market risks, returns to labour and farm income.

BEST PRACTICE RESEARCH METHODS FOR SMALLHOLDER CASI

For the purposes of this paper, the discussion of CASI research practices is organized by common stages of the research cycle (Figure 2), embracing background scoping, research and partnership design, targeting of research areas and diagnosis of constraints, field research and analysis, investigation of value chains, institutions and policies (which can precede or be merged with field research and analysis) and scaling and spillovers of the identified innovations. Feedback loops exist within and between most stages. Management and reporting relate to all stages. The integrated nature of CASI, the tailoring to specific farming systems and the importance of synergies and tradeoffs call for specific adjustments of standard agricultural research methods, for example on-farm trial designs of zero-tillage and residue retention in crop-livestock systems. Annex Table 2 highlights some aspects of research methods and their adjustment for CASI.

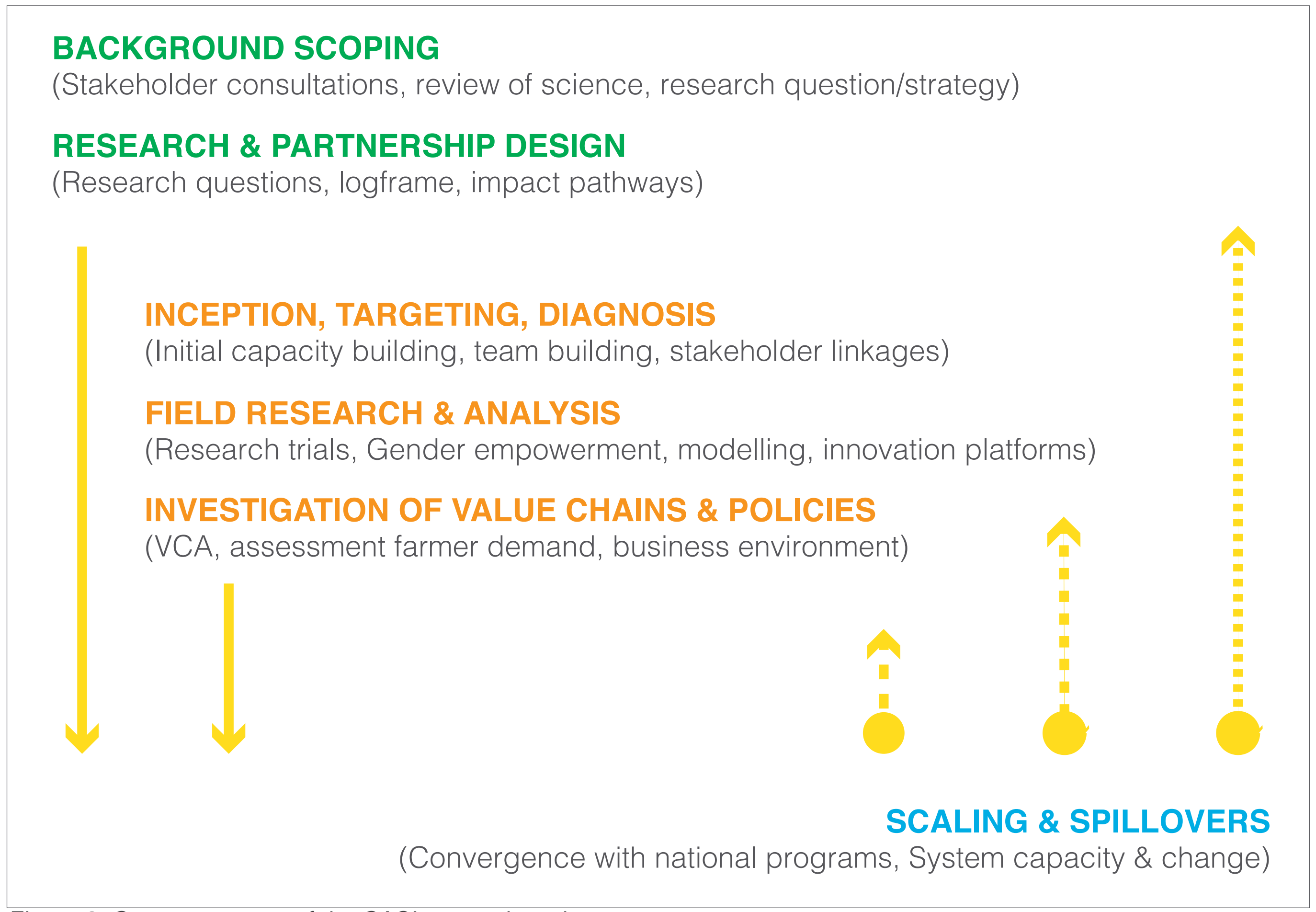

Figure 2: Common stages of the CASI research cycle

Farmer showing his locally made no-till planter, Pakistan

“Notwithstanding the obvious contrasts between countries in farm sizes, equipment and institutions, there are many opportunities for cross-learning about CASI technologies and research management.”

Background scoping

Poor background scoping and preliminary analysis is a common shortcoming which hampers sound research design and ultimately implementation efficiency, especially in the case of CASI. The synthesis of previous research findings and development experience and stakeholder consultations refines the overall research question and checks the potential relevance of CASI solutions for the local farming systems (including soils, climate, farming systems, social capital and market access) as well as farmer and policy priorities (on food systems, environment and sustainability) and impact pathways (or theory of change). Another series of key scoping activities involves consultations with prospective partners, including the private sector and stakeholders dealing with environment, scaling and development. Experience shows that at least one brainstorming and synthesis workshop with partners is of immense value.

Background scoping was important for the design of all the large ACIAR partnerships listed in Annex Table 1. As one exemplar, the SIMLESA Program in eastern and southern Africa and Australia was scoped with key partners over approximately one year. The consultations were based on two underlying principles: African national ownership and co-investment, and the validity of an Africa-Australia science ‘bridge’ which opened possibilities of post-program research collaboration. The diverse, complex, fragmented and subsistence-oriented nature of African smallholder farming systems meant that there was limited scope for an input-intensive, ‘one-size fits all’, approach. Thus, a regional CASI research strategy was sketched with sufficient flexibility to accommodate country and local differences.

In the absence of scoping, other ACIAR projects have found simple pre-project workshops with core partners and scientists useful for identifying core elements of research strategy, pathways to impact, vision of success and progress indicators – however, workshops alone are not a substitute for background analysis. During background scoping of large research initiatives, foresight studies are useful to check on the probable future relevance and ‘fit’ of the likely CASI research outputs. Simple models of the target systems generally augment understanding of system components, interactions, constraints and future opportunities for CASI. Based on the experience of ‘kickstart’ cropping system modelling undertaken as part of SRFSI scoping, further thought should be given to the specification and timing of such preliminary models for future projects.

Research & partnership design

The project research questions and research strategy outlined during scoping should drive negotiations during research and partnership design. The research agendas listed in the previous section of this paper represent a checklist of potential CASI research topics which could be considered. CASI research strategies generally include diagnoses, on-station trials, on-farm trials, simulation modelling and analysis of value chain, policy and scaling environments. Gender empowerment and capacity building of partners are important themes. Plausible pathways to adoption and impact targets are outlined. Logframes are a common format for systematic specification of research outputs and planned inputs and activities; and also facilitate the development of monitoring indicators. Many CASI research questions require interdisciplinary research, and thus research designs should provide for adequate multidisciplinary science teams backed by specialist expertise where required. The design of governance can influence research leadership and the efficiency of interdisciplinary research. In one effective model, the SIMLESA Program Steering Committee comprised senior representatives (often the research DG or DDG) from participating countries with independent co-chairs from Africa and Australia.

The on-farm research component is a core element of design. CASI research in Asia and Africa can have far greater numbers of participating farmers than is the case with domestic research in Australia. However, to take full advantage of the larger on-farm research programs and the opportunities from CASI, capacity building of partner country scientists, field technicians and farmers is important – and provision needs to be made in the research design and project plans from the outset. Some research designs include field and laboratory research in Australia to complement the CASI research in partner countries. Notwithstanding the obvious contrasts between countries in farm sizes, equipment and institutions, there are many opportunities for cross-learning about CASI technologies and research management: SIMLESA in Africa, Conservation Cropping and CANA in the Middle East and North Africa and SRFSI in South Asia all benefited significantly from cross-country learning.

In practice, the selection of partners and the finalization of the research design are inter-dependent. The complementarity of partners’ mandates and priorities is critical and underpins the ownership and commitments the partnership. Many national partners give a high priority to food security and adaptation to climate variability, for which CASI is well suited. A mix of research, development, policy and business partners (or networks) with appropriate capacity on food and environment topics underpins effective CASI research projects. Private sector involvement is a common theme in CASI research designs. As examples, SIMLESA collaborated with seed companies in east and southern Africa, and SRFSI engaged with zero-till drill manufacturers and micro-entrepreneurs for service provision of drills and other inputs – and similarly with the Happy Seeder Policy project. The Conservation Cropping project supported the manufacturing of planting equipment by small workshops in Iraq and Syria (which continued to operate post-project) and a medium size Jordanian manufacturer (which subsequently discontinued production). The CamSID design included a small business management research component backed by business management specialists.

Inception, Targeting & Diagnosis

These three activities frame and focus the main research of the project, and ideally can be completed and reported within the first 3-6 months of project life. Inception workshops are the venue for ensuring a good understanding of the overall CASI research design, strategy and work plans by all partners and scientists. The application of team building methods facilitates the establishment of the trust required for transdisciplinary or interdisciplinary research spanning disciplines, partners and sometimes countries. In the case of SIMLESA, the outcomes of stakeholder consultative planning workshops held at both service provider and farm levels fed into discussions at the SIMLESA Program launch workshop, ensuring CASI research activities were well focussed and aligned well with national and regional priorities. The CamSID project organised back-to-back inception, foresight, stakeholder and planning workshops which were very effective in the Cambodian context.

The location of CASI research sites is a critical aspect of targeting, based on the research questions, farming systems characteristics, community preferences and the experience of local researchers. Development agencies need to be involved, with a view to interim and long term scaling. SIMLESA and SRFSI selected research areas with contrasting agricultural and sustainable development potentials, and representative of substantial areas for potential scaling of the research results. CANA identified three contrasting and complementary research platforms across the Magreb region (one per country) thus maximizing the value of research results and creating conditions for co-learning and inter-country spillovers.

After research sites are confirmed, participatory field diagnoses often become the first major test of multidisciplinary team management and performance. Sometimes the competencies and experience of team members with the well-known participatory diagnostic methods and the CASI approach need to be refreshed. A good understanding of CASI targets the probing of key issues in the local farming systems, such as soil management, crop-livestock interactions, equipment and herbicide service providers and the multiple criteria applied in decision making by farm women and men.

Field research and analysis (farms, communities, landscapes)

Along with the analysis of value chains, institutions and policies (discussed in the next sub-section), field research in farms, communities and landscapes represents the core of CASI research. Ideally, CASI field research would be underpinned by a synthesis of existing natural resource and farming systems knowledge pertaining to fields, farms, communities and landscapes (or watersheds). Participatory on-farm research trials and associated farmer demonstrations have delivered valuable results in ACIAR projects investigating CASI. The final review of SIMLESA observed that the application of standard research protocols across eight participating countries was an outstanding strength of the Program, enabling regional analyses and creating a powerful regional database of research results.

In CASI research the zero-till and crop residue retention experimental treatments incorporate selected treatments of improved cultivars, soil management and agronomy. The practices must be affordable and adoptable by farmers. Where cropping interacts with livestock, both grain and forage crops become relevant, as in SIMLESA and CANA. Environmental outcomes, notably soil properties and erosion, have been monitored in several CASI projects. Flexible step-wise sequences of CASI components, tailored to site environments and farmer needs, underpin SIMLESA research.

The resilience of CASI should be analysed along with productivity improvement and environmental outcomes. Where returns to water or labour are critical drivers of adoption and system change, water and labour productivities should be analysed. The documentation and reporting of innovations and lessons in the adaptation and use of zero-tillage machinery is particularly important for CASI. To assist with the sharing of lessons from research implementation, the Conservation Cropping project developed a comprehensive CASI manual, published in English and Arabic (Loss et al. 2015).

A clear distinction between the roles of farmers and researchers in the design and management of trials is important. In this regard, farmer-managed trials for which farmers meet the costs of inputs are the 'gold standard'. In northern Iraq the sole external input provided by the Conservation Cropping project was access to a no-till planter, and this was replicated most successfully by the NARS and workshops in Syria. In these cases, participating farmers had ownership of research activities and results, which enabled effective farmer-to-farmer learning.

In CASI research APSIM (or other crop models) is used to test the implications of changed cultivars, cropping patterns, planting dates, fertiliser regimes and other management practices. It was also used to appraise the performance and resilience of the cropping systems under past or alternate climate series over many years. Modelling was used to assess cropping system resilience in SRFSI because of the extreme climatic variability in the Eastern Gangetic Plain. Such modelling was applied in SIMLESA to evaluate the potential long term feasibility of different combinations of labour availability, crop establishment techniques and prevailing weather patterns (Nyagumbo et al. 2017). Consideration should be given to planning CASI modelling activities for the early delivery of results as an input to field research designs.

For crop-livestock systems the incorporation of livestock feed into whole farm models enables the analysis of crop residue management (for use as soil cover or livestock feed). Systems modelling analysed the riskiness of various CASI technologies. Whole farm models that incorporate the crop and livestock enterprises, household food consumption and environmental outcomes, such as APSFarm developed by SIMLESA, are effective for CASI modelling – and allow technology evaluation at the key level, viz, the farm.

Investigation of value chains, institutions and policies

Socioeconomic household surveys, using formal and informal interview techniques, were commonly applied in CASI research projects. Such surveys have multiple purposes, including the assessment of value chains, local institutions (including markets) and agricultural services (including extension). They can also contribute to the evaluation of on-farm research trial results and set the benchmark for subsequent evaluations. Multidisciplinary team input to the household survey questionnaire and analysis ensures appropriate coverage of relevant themes on resources, input use, environment, gender, youth and private sector, inter-component interactions and synergy with the research trial data. The scales of household surveys varies substantially, from 5,000 households across five countries in SIMLESA to dozens of households in CANA and CamSID. By repeating the household interviews after several years, SIMLESA established a valuable panel data base. Progress along impact pathways can be revealed by adoption surveys (Boulal et al. 2014). Mixed research methods are often effective for analyses of value chains, institutions, gender empowerment and inclusivity of marginalised groups. SIMLESA investigated the implications of CASI for gender empowerment and CamSID examined gender roles in the rice value chain and agricultural cooperatives, depending on both quantitative and qualitative data from participatory focus group discussions.

Data collection, analysis and reporting are often key operational challenges, especially for on-farm trials and household surveys. Electronic data capture is recommended; however, the transition from the traditional manual methods requires good planning, organization and management. The trial and survey datasets should be made available to all researchers under FAIR guidelines: Findable, Accessible, Interoperable and Reusable (CAST 2019). A clear understanding of data sharing arrangements is essential from the start of projects so as to ensure all parties are clear about their roles and responsibilities for the generation and sharing of credible datasets.

Alongside technical innovations, CASI institutional innovations are also important for farmer-to-farmer learning, participatory evaluation and adoption of technical innovations, and some can be disruptive and transformative. Increasing attention is being paid to farmer groups, social capital and innovation platforms. Micro-finance groups and marketing cooperatives can improve CASI's performance. SRFSI identified successful farmers' clubs which were managing no-till machinery services, purchasing farm inputs and marketing produce; one was providing contract zero-tillage maize crop establishment in neighbouring villages. Water user groups and other farmer groups support many aspects of CASI and good agricultural development. Participatory assessment and case study methods are suitable for the investigation of social capital and institutional innovations.

Most CASI projects established innovation platforms in research areas with farmers, extension agents and researchers, input and produce traders, NGOs and other interested development actors. Figure 3 illustrates the multi-stakeholder aspects of the CANA innovation platform model, with 10 actors involved alongside farmers and researchers. The platforms foster co-learning and adaptive innovation (see also Makini et al. 2013). There are 58 innovation platforms in SIMLESA, and about 30 or so across SRFSI.

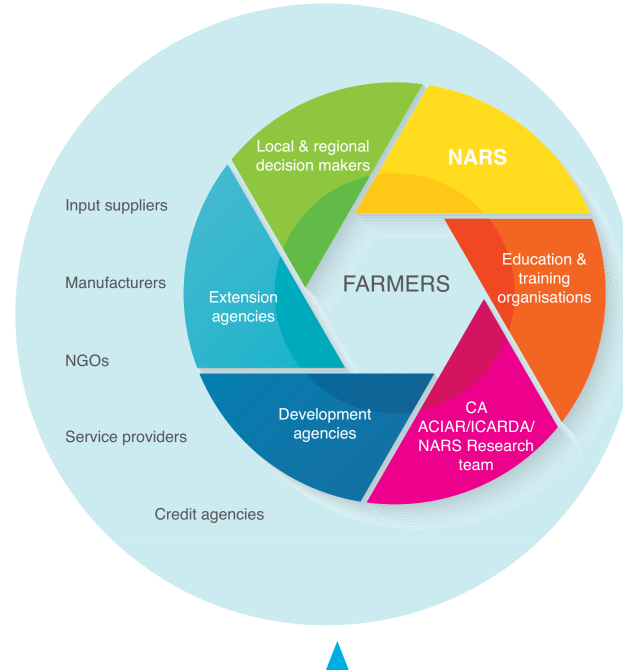

Figure 3. CASI research innovation platform (CANA project)

Scaling & spillovers

Seeking wider development impacts of CASI innovations beyond the immediate areas around innovation platforms, SIMLESA and SRFSI initiated research on different scaling approaches (avoiding simplistic linear technology transfer approaches). These systems based approaches to scaling require broader partnerships and constructive engagement with national development programs. Ideally, scaling actors should be involved from the commencement of the research project in order to understand the institutional, capacity and infrastructural requirements for rapid adoption of the identified innovations. From a larger perspective, there are critical research questions related to efficient scaling processes which merit specialist investigation.

SRFSI has explored the convergence of CASI research with major national agricultural and rural development programs, especially in the State of West Bengal. SRFSI identified a number of other accelerators of CASI scaling, including no-till drill provision through farmers' clubs or other entrepreneurs, investment in innovation platforms and competency building of extension agents. The Happy Seeder Policy project fostered evidence-based policy dialogues on strengthening manufacturing and supply chains of the no-till drills, including the Happy Seeder, to rice-wheat farmers. SIMLESA deployed competitive grants to support the testing of diverse scaling mechanisms,

Single row no-till planter at SIMLESA innovation platform field day, Uganda.

from TV media broadcasts to improved seed distribution.

Several studies have shown that spillovers between jurisdictions account for a substantial portion of the returns to research in the USA and in developing countries. For example, the Rice-Wheat Consortium in South Asia generated high pay-offs from the coordination of research into resource conserving technologies (a forerunner of CASI) across the rice-wheat farming system of South Asia and the spillover of knowledge and results between countries. At the regional Happy Seeder project workshop NARS leaders from four South Asian countries agreed in principle to the establishment of the South Asian Regional Platform for CASI. There is scope for research on the determinants of spillover effectiveness in different contexts.

Management, evaluation & reporting

Strong leadership is a sine qua non for effective interdisciplinary CASI research, and applies in all stages from scoping to spillovers, and from the coordination of research site activities to the management of CASI research partnerships. CASI research benefits from the principle of adaptive management, adjusting as appropriate to results of active monitoring, annual science meetings and periodic reviews.

Sustainability is a cross-cutting theme which in the past received insufficient attention. However, this aspect is improving. SIMLESA detected impressive reductions in soil erosion from CASI in Africa, and SRFSI measured seasonal aquifer levels and water use at field level in the Eastern Gangetic Plain.

During scoping CamSID designed a comprehensive set of indicators of sustainability embracing environment, economics and social indicators. Useful tools for this purpose are becoming available, such as the Sustainability Assessment Indicator Framework developed by the Sustainable Intensification Innovation Lab (Kansas State University).

CASI innovations require evaluation at multiple scales, and with sufficient breadth to capture the diversity of CASI outcomes and impacts. Key dimensions include CASI adoption, household and community benefits, environmental impacts and sustainability outcomes (environmental, economic, social and equity effects). The valuation of externalities requires non-market methods.

Reporting of CASI should reflect the systems outcomes from interdisciplinary research. The synthesis often involved in the reporting process is valuable, particularly when prepared by multidisciplinary research teams. Reporting is under-utilised as a communications tool, despite its value for the full research team and external stakeholders as well as for accountability to the financial partner.

REFLECTIONS ON IMPROVEMENTS IN CASI RESEARCH METHODS

During the coming decade leading up to 2030, the SDGs' target year, NARS and private sector capacity for CASI research will continue to grow substantially but the pressure will grow for increased food crop productivity and enhanced natural resources.

Although existing research methods have served CASI well, there is scope for improvement to enable systems research to address site specific local issues (accompanied by smart spillover methods) while also contributing to generic research questions. Prevailing economic and scientific trends will stimulate private investment in agricultural research methods, especially those related to digital applications, artificial intelligence, decision support tools, sensors, modelling and value chains, in the pursuit of intensification and economic growth. However, effective public-private innovation partnerships addressing such global challenges would benefit from complementary public methodological development in certain areas, including the role of CASI in contributing to non-market aspects of externalities (e.g., air and water pollution), food systems, resource management and climate change. Appropriate regional research infrastructure, such as soil laboratories, would facilitate application of improved research methods.

The following paragraphs outline ten opportunities for research method development by 2030 that would transform CASI research and contribute to the sustainable development of agriculture.

Systems research

The refinement of systems research methods would enable more holistic investigations of CASI. At relatively low cost, conventional Farming Systems Research (FSR) methods could be enriched and tailored to the needs of CASI at multiple-scales. Five improvements of FSR would be valuable: transdisciplinary research processes; real-time whole farm and landscape simulation modelling, based on electronic input from sensors and producers; participatory preference assessment and decision matrices spanning intensification and sustainability outcomes and SDG targets; a CASI Sustainable Assessment Indicator Framework; and CASI matrix of readiness for scaling of CASI within farming systems and countries.

Weed management

Weeds are a high priority technical constraint for CASI that is increasing in severity but which have received insufficient research, especially in relation to non-herbicide based solutions. Herbicide-resistance has appeared in mechanized large-scale cereal farming systems, especially in monocultures without crop residue retention or grazing livestock. Where herbicide-resistant weeds are already prevalent e.g. in NW India (Heap 2019) alternative approaches are urgently required. Thus, the development of herbicide-free weed control practices is a high priority.

Climate smart agriculture

The tailoring, testing and evaluation of CASI for Climate Smart Agriculture (CSA) would benefit from better knowledge of farming system resilience and adaptation to climate stresses and shocks. For this purpose, improved research methods are needed for dynamic whole farm modelling, the measurement of farming systems resilience and the investigation of risk management behaviour by farmers and value chain operators.

“The demands of a growing and wealthier global population and the threats from climate and international market volatility require productive, resilient and sustainable approaches to agricultural transformation such as Conservation Agriculture based Sustainable Intensification (CASI).”

Management decision making

Management decision making techniques need to be adapted for the multiple criteria and risk aversion of farm women and men in relation to CASI adoption, adaptation and management, with the incorporation of relevant insights from behavioural science. Decision support tools and smartphone based information services need to provide integrated content on CASI, reflecting market and climatic aspects as well as technological elements. Similarly, rural entrepreneurs and CASI equipment service providers would benefit from improved decision support tools.

Institutional research

Institutional challenges for CASI include inadequate social capital and institutional failures resulting in poor incentives for CASI adoption, zero-till equipment manufacture and service delivery to smallholders. Thus, CASI research would benefit from practical field methods to analyse institutional failure and stakeholder incentives, as well as interdisciplinary methods for the analysis of innovation platform performance.

Scaling & spillovers

The scaling of CASI innovations is a great opportunity for action research because the approaches for scaling complex innovations such as CASI are still being developed. Such scaling research could take advantage of the contrasting institutional, policy and agroecological environments where CASI is presently being scaled. Similarly, systematic mechanisms for spillover of CASI research results across farming systems and countries need to be developed.

Targeting methods

Improved prioritization and targeting methods for CASI research (and scaling) within regions and countries would enhance the identification of priority farming systems for CASI research and development, potentially building on the FAO/World Bank global characterization and mapping of farming systems (Dixon et al. 2001). Complementary national and project area farming system characterizations would also be of value. Such targeting also facilitates effective sharing of research results.

Policies and institutions

Improved methods for evidence-based policy dialogues regarding policies and institutions to foster CASI uptake are required. Because of widespread policy failure and even perverse outcomes, low cost methods for continuous farmer and community monitoring of policy impacts, say smartphone based, would be valuable.

Linkage to food systems

The linkages between CASI, farming system diversification and food systems need to be better articulated and operationalized. Often, diverse farming systems encourage diverse rural diets and reduced rural malnutrition. The links to urban food systems through food markets and value chains needs to be appraised.

Regional platforms for spillovers

Much CASI research is fragmented across countries and regions, so that NARS with limited capacity are often unable to take advantage of current CASI research results and research methods. Thus, regional platforms to share knowledge on CASI innovations, institutions and scaling experience are valuable, building on the experience of the Rice-Wheat Consortium in South Asia or several the ACIAR supported multi-country CASI research partnerships. Two prospects are worth noting: the support of Ministers of Agriculture in eastern and southern Africa for CASI knowledge sharing, and NARS agreement in principle to establish a South Asian Regional Platform for sharing CASI knowledge.

Sharing impacts from Conservation Agriculture based Sustainable Intensification (CASI), South Asia

CONCLUSIONS

The demands of a growing and wealthier global population and the threats from climate and international market volatility require productive, resilient and sustainable approaches to agricultural transformation such as Conservation Agriculture based Sustainable Intensification (CASI). The CASI approach integrates strengths of Conservation Agriculture and Sustainable Intensification, and the dual goals of food security and natural resource management of CASI resonate with many international and national policy makers.

ACIAR has supported international research partnerships that tested CASI in rainfed and irrigated farming systems in Asia, the Middle East and Africa with good results. These research partnerships adapted and deployed inter-disciplinary research methods, delivered important science knowledge and impacts with hundreds of thousands of farmers and built relevant capacity and policy awareness. Interdisciplinary methods were applied for scoping (when implemented), research and partnership design, field research, investigation of markets and policies and scaling. Some specific adaptations of methods for CASI research included interactions between no-till farm equipment, improved varieties and good agronomy practices, or between crop residue retention as soil cover and the feed demand of livestock.

While existing research methods have produced a substantial body of CASI knowledge, on reflection there is considerable scope to strengthen CASI research methods during the coming decade. Ten opportunities for method development are suggested: systems research; weed management; climate smart agriculture; decision-making; social capital and institutions; scaling; targeting; policy; food systems; and (regional) spillover management.

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ANNEXES

Annex Table 1: Key aspects of selected ACIAR international research partnerships on CASI

RESEARCH PARTNER-SHIP (YEARS)	REGION	FARMING SYSTEM (MAIN CROPS, LIVESTOCK)	LEADING RESEARCH PARTNERS	FEATURED RESEARCH PRACTICES	SUPPLEMENTARY NOTES
SIMLESA (2010-19)	East & Southern Africa (8 countries)	Maize mixed (maize, beans, pigeon pea, etc, cattle)	CIMMYT, 8xNARES, UQ	Strong country & regional ownership, multidisciplinary national research teams, risk reduction goal, baseline & panel household surveys, farm simulation, innovation platforms, scaling methods, competitive grants, active synthesis of results	Major 8-country regional operation. Extensive capacity building (short course, degrees). Demonstrated performance of CASI and adoption by more than 480,000 smallholders
CANA (2012–15)	Magreb, North Africa (Tunisia, Algeria, Morocco)	Agropastoral (wheat, barley, pulses, sheep)	ICARDA, 3xNARES, Rural Solutions	Selection of regionally-relevant research hubs in each country, research group regional tours, active involvement of extension & business alongside researchers in innovation platforms, leading farmer researchers graduate to demonstrators then CA information disseminators	Effective innovation systems approach which built on many decades of SA & WA assistance for dryland farming in the region. Inclusion of CA components into agricultural policies
Conservation Cropping (2005-2014)	Middle East (Iraq, Syria)	Agropastoral (wheat, barley, pulses, sheep)	ICARDA, 2xNARES, Uni SA, UA, UWA	Attempt to separate the benefits of the 3 pillars of conservation agriculture with emphasis on zero-tillage to enable early sowing. Support to farmer and manufacturer innovation with equipment, active role for private sector. Participatory on farm testing and demonstration of zero-tillage.	Increased fuel prices, high personal safety risks for farmers and yield benefits of early sowing stimulated adoption of zero-till practices
SRFSI (2014-20)	South Asia (Bangladesh, India, Nepal)	Rice-wheat (rice, wheat, legumes, cattle)	CIMMYT, 3xNARES, CSIRO	Nearly 1000 participatory OFR, crop simulation, farmers clubs and service providers, convergence with State and national development programs	Targeted extensive poverty and severe climate change pressure. Involved 21 partners across 3 countries
CamSID (2016-21)	Mekong region (Cambodia)	Lowland rice (rice, mungbean, vegetables, fish)	Univ Sydney, 1xNARES	Foresight and stakeholder dialogues at inception, active business research component, clear target indicators of sustainability, e-surveys	Remittance-based livelihoods. Effective collaboration with research, extension and Universities.
Happy Seeder Policy (2017-18)	South Asia (Bangladesh, India, Nepal)	Rice-wheat (rice, wheat, legumes, cattle)	Univ Adelaide, 3xNARES	Mixed methods value chain analyses for happy seeder no-till drills, national and regional policy dialogues with key stakeholders	Response to air pollution from burning rice straw. Gov India subsequently launched strong support for the supply of zero-till drills in N W India. NARES leaders signed agreement for South Asian knowledge sharing Platform for CASI

Refer to notes on the following page

ANNEX TABLE 1 - NOTES

SIMLESA – CSE=2009-024/CSE-2013-008 Sustainable Intensification of Maize-Legume Cropping Systems for Improved Food Security in Eastern and Southern Africa Program; CANA -- CSE-2011-025 Adapting conservation agriculture for rapid adoption by smallholder farmers in North Africa; Conservation cropping -- CIM-2008-027 Development of conservation cropping systems in the drylands of northern Iraq ; SRFSI – CSE-2011-077 Sustainable and Resilient Farming Systems Intensification Project; Happy Seeder Policy – CSE-2017-101 Value chain and policy interventions to accelerate adoption of Happy Seeder zero tillage in rice-wheat farming systems across the Gangetic Plains; CamSID -- CSE-2015-044 Sustainable Intensification and Diversification in the lowland rice system in NW Cambodia. There were many notable projects. Other recent ACIAR projects have supported research on CASI, especially associated with soil management, irrigation water management and crop-livestock integration. Among the earlier generation of ACIAR conservation agriculture projects, a particularly successful project was LWR2/1999/094 (later as SMCN/1999/094) Improving the productivity and sustainability of rainfed farming systems for the western Loess Plateau of Gansu.

Annex Table 2: Key aspects of selected CASI research methods

STAGE OF RESEARCH CYCLE	SELECTED GOOD RESEARCH PRACTICES USED FOR CASI (& EXAMPLE PROJECTS)	KEY ADJUSTMENTS IN PRACTICES FOR BEST CASI RESEARCH
Background scoping	• Synthesis of prior research results & uptake (all) • Extensive stakeholder consultations (SIMLESA, SRFSI) • Identify prospective research & scaling core partners, alignment of priorities, capacities (all) • Foresight studies (CamSID during Inception) • Core elements of design including overall research questions & strategy, impact pathways & core partners	• Identify possible CASI practices by different farming systems (soils, climate, crops, livestock, social capital, markets) for research & scaling • List key interactions across disciplines for CASI (SIMLESA) • Include equipment suppliers in stakeholder consultations, consider as partners (SRFSI, CANA, Conservation Cropping) • Ascertain CASI competencies (& priority training needs) of prospective partners (SIMLESA) • Indicative modelling to understand farming systems & inform research questions (SRFSI)
Research & partnership design	• Clear alignment to national priorities, especially in relation to food security, environment and sustainability; strong country & regional ownership (SIMLESA) • Systematic selection of partners (CamSID) – & assurance of science/resource contributions, but not all partners have strong CASI expertise • Specify multiple goals, pathway to impact, research strategy, research questions (CANA) – easier with prior workshops/consultations • Clarify sustainability indicators & MEL (CamSID) • Establish equitable governance arrangements (SIMLESA)	• Involve Environment & Climate Departments alongside Agriculture • Because of complexity & knowledge-intensiveness, CASI requires extra seasons for field trials cf. fertilizer, planting date or other agronomy trials • Include scaling & Dept. Environment representatives in governance arrangements
Inception, targeting & diagnosis	• Establish multidisciplinary national research teams (SIMLESA) • Review foresight findings (CamSID) • Re-connect with key stakeholders especially related to scaling & policy makers (SRFSI) • Confirm selection of relevant research hubs & conduct & report participatory site diagnoses • Rapid e-enabled multi-disciplinary participatory diagnoses with quick reporting • Advance training of CASI concepts & field research methods to ensure quality implementation (SIMLESA)	• Include environment stakeholders to explore intensification-environment win-win strategies & institutional linkages • Involve major scaling & policy actors from research inception • Consult with CASI equipment & service providers, usually business • During diagnosis, elicit resource & production interdependencies, & attitudes to risk; communicate key features of CASI to farmers during diagnosis, before ranking of options
Field research & analysis (farms, communities, landscapes)	• Initiate innovation platforms with farmers, researchers, extension, business, district officials • Establish OSR trials • Establish OFR trials as a first priority (SRFSI), supported by innovation platforms • e-data collection on trials by well-trained technicians/ farmers • e-household surveys (baseline & panel) • Quick basic analysis of data (annually for trial data; within a year for baseline surveys) • Timely posting of cleaned trial & survey data (within 12 months) to open access databases • Farm system & risk simulation (SRFSI, SIMLESA)	• Negotiate community approval of OFR, management of irrigation & control of grazing livestock (SRFSI) • Ensure OSR, OFR & household surveys reflect the intensification (& diversification) & sustainability goals (SRFSI, CamSID) • Reflect gender differentiation & ensure women's empowerment • Whole farming system modelling & simulations, incorporating crop & livestock interactions especially feed, & farm risk management (SIMLESA)
Investigation of value chains, institutions, policies	• Mixed methods value chain analyses (Happy Seeder Policy) • Policy maker & stakeholder engagement (SIMLESA, SRFSI, CANA) • Pilot farmers clubs & service providers (SRFSI) • Engagement with local seed companies (SIMLESA)	• CASI requires analysis of multiple input (notably herbicide & no-till planters) & produce chains (SRFSI) • Involvement of equipment manufacturers (Conservation Cropping, Happy Seeder Policy, SRFSI)
Scaling & spillovers	• Match technologies & impact pathways to each farming system zone (SRFSI) • Build on public & business stakeholder relationships developed from start (SIMLESA) • Convergence with State & national development programs (SRFSI) • Massive extension, NGO & farmer competency building (SRFSI) • Policy dialogues (Happy Seeder Policy)	• Note complexity of & interactions in CASI technology, chains & pathways to impact • Emphasize food, income & livelihood benefits to farmers; seek focused investment form programs on equipment service providers & training on CASI
Management & reporting (ongoing)	• Systematic synthesis of results (SIMLESA) • Brochures, briefs & media for different users (farmer, extension, policy makers, business – Conservation Agriculture in Middle East: Manual • Policy dialogues with key stakeholders (Happy Seeder Policy)	• Strong leadership & management of interdisciplinary research • Present joint CASI outputs & benefits as well as separate component effects • Test CASI extension briefs & media with different types of farmers • Communicate multi-scale benefits of CASI to policy makers • Emphasize positive environmental & sustainability outcomes (e.g., improved soils, reduced air pollution) • Reinforce CASI knowledge sharing mechanisms, e.g., agreement for South Asian knowledge sharing Platform for CASI

REFLECTIONS ON INTERDISCIPLINARITY IN AQUACULTURE AND FOOD SYSTEMS RESEARCH FOR DEVELOPMENT IN AUSTRALIA AND THE PACIFIC REGION

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Gail Ngalwungirr collecting sea cucumbers on Goulburn Island, Australia.

BIOGRAPHICAL NOTES

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ABSTRACT

This essay explores various definitions of research interdisciplinarity and its value to research for development (RforD) in conceptualizing and informing responses to complex problems at the interface between society and nature. Two case studies, from northern Australia and the Pacific region, ground the discussion but we also comment more broadly on the challenges of 'doing RforD'. The essay briefly explores alternative typologies of agricultural RforD and the relations between interdisciplinarity and the people-centred pluralism that has emerged from the development literature. We discuss their relative value in conceptualizing and simplifying complex problems, in offering more fit-for-purpose project design and whether they go far enough in articulating processes and actors through which research is translated into outcomes and impacts. We conclude that approaches that are creative, grounded, integrative, reflexive, and alert to power may well be a sufficient definition to guide good RforD.

INTRODUCTION

Across a range of fronts, from the Sustainable Development Goals (SDGs) to local-scale interventions in rural communities, conceptualizing and doing research for development (RforD) is becoming more complicated and increasingly accountable for development outcomes. The breadth and diversity of indicators for the SDGs, for example, make clear that research needs to be framed more broadly, to include more scientific disciplines, new partnerships and world views. This trend seems common to many jurisdictions as donor governments seek greater visibility for their investments, and reporting of development outcomes over shorter timeframes. Theories of Change have become all-pervasive in program design. Internationally, this drive to accountability is exemplified by the CGIAR (an international consortium of agricultural research centres). The CGIAR Strategic Results Framework has a target to assist 100 million people, of which 50% are women, to exit poverty by 2030 (https://www.cgiar.org/how-we-work/strategy/). For the reform-minded CGIAR, this is high ambition and exemplifies the contemporary challenges facing RforD.

Although understandable in many ways, the greater focus on development outcomes increasingly challenges RforD projects to 'move further along the development pathway' in order to make their impact targets credible, or even plausible. So how is research changing to meet the challenges we see down the road? The need for research that is better able to tackle deeper and more complex issues at the interface between nature and society is clear, but what that 'looks like' and how it is different from what has gone before is less clear. As we move from the laboratory (real or virtual) into the realm of sustainable development, values, culture and other guides to making sense of research come into play. These trends make the design and implementation of projects much tougher.

In this short essay, we offer personal reflections and opinions on the challenges in taking broader views of the RforD challenge. To do this properly we would need much more time and space in order to venture down the many curious and fascinating rabbit holes in transdisciplinarity-land (e.g. what is a discipline?). Our brief was to offer opinions and reference lightly, which may make this an unrewarding read for some.

We are ecologists/biologists by training, but have increasingly been drawn to working on problems outside our specialisms – a common career course for people working in RforD. We use two case studies from our experience to ground the discussion but also draw on broader reflections on the challenges of 'doing RforD'. First, we use an ongoing program of work funded by the Australian Centre for International Agricultural Research through two projects on fisheries and food security in the Pacific region. This work is current and lessons continue to be learned about how we operate. We also reflect on a successful and ongoing Australian government program to develop aquaculture enterprises with Indigenous groups in the Northern Territory, which works with remote Indigenous communities to deliver policy outcomes towards Indigenous economic development goals.

MODES OF RESEARCH – WHAT IS IN A NAME?

A common response to the complexity and importance of agricultural RforD is to make research 'multidisciplinary (MDR)', 'interdisciplinary (IDR)', or even 'transdisciplinary (TDR)'. These terms mean many things to many people and by their nature may defy simple and universal definition. Whether this definitional ambiguity and confusion is actually a problem depends on how the terms are used; they serve both descriptive/analytical and normative purposes. If it is the latter, then multiple meanings are less an issue because the terms may be repurposed to create narratives for change. So common are these terms in academia, they almost have vernacular meaning: 'if it's interdisciplinary it has to be better, right?'

Much of the IDR/TDR literature appears focused on exploring conceptual landscapes, developing methods, and defining what they are and are not. Those landscapes are contested and, like the evolution of concepts about 'resilience', this process may be seen as necessary to the maturation of a, well, discipline (Brand and Jax 2007).

Interdisciplinary research is differentiated from MDR (bringing together research disciplines) by an ambition to blend frameworks and theories across conceptual and epistemological boundaries. This integration or hybridization, it is thought, creates insights not otherwise possible, and is needed to better address complex problems (Huutoniemi et al. 2010). As a further step, transdisciplinary research (TDR) is even harder to differentiate. Several attributes seem to differentiate it from IDR, but inconsistently so, and some definitions of TDR resemble those for IDR. Recurrent themes in defining TDR include: release from the blinkers of disciplinary work, greater reflexivity, and participatory enquiry. Leontine Visser (2004) uses the elegant metaphor of 'excursions in transdisciplinarity' – the notion that when you return home from a journey into another discipline you are changed and so more likely to reflect on your own disciplinary assumptions and methods. And, by inference, more likely to take such an excursion again. Visser's TDR looks a lot like the IDR of others. Brandt et al. (2013) identify research as being potentially transdisciplinary if at least two scholarly disciplines and practitioners are involved, but this falls short of the transcendent tone of other definitions. At the limit, transdisciplinary research could be a post-normal free-for-all, in which contestable alternative truths are constructed and deconstructed. This sounds like creative fun but it is difficult to see what would translate into improved lives, or be fundable.

As most usually described in the literature, IDR remains within the domain of researchers – new epistemological or theoretical insights are cited as motivations for pulling together interdisciplinary teams (e.g. Klein 2008, Huutonniemi et al. 2010). In other framings, IDR is a mechanism to coalesce researchers and practitioners around complex AND important problems. Sustainability Science (Clark and Dickson 2003, Kates et al. 2001) is a good recent example of this ambition.

FRAMING FOOD & FISHERIES IN THE PACIFIC REGION

Food and nutrition security in the Pacific region is complex and contingent. It is moulded by many forces, large and small including: production, culture, trade, colonial legacy, images of modernity, and the daily small things that influence the way people live their lives. Trying to make sense of such complexity requires a framework to organize thinking, people and to help create simplifying narratives for change.

For some authors, creation of a common conceptual framework is a key attribute of TDR. In one of our projects we frame the food and nutrition security problem in the Pacific region as a food system. A food system may be defined as that set of interacting activities and outcomes that encapsulate the production, processing, trade, and consumption of food (Sobal et al. 1998, Erickssen 2008, Ingram 2011, FAO HLPE 2017). Integration of these activities and outcomes connects agriculture and nutrition, and emphasizes social and biophysical drivers as well as the public health outcomes that come from it.

Rather than being created to accommodate different academic disciplines, this problem-based framing was designed to provide a better definition of the problem and to articulate with pathways to impact. There are many alternatives, but 'food systems' seems to encapsulate several important concepts: complexity, scale-dependence, connectedness. 'Food' itself is an integrating idea – to make progress in sustaining food, we need to connect supply, availability, affordability, choice and the outcomes of its consumption. Food systems have both structure and agency embedded in how they work.

Our anthropologist colleagues recoil at the word 'system', but we do not use the term food system in the cybernetic sense of a closed set of linkages and feedback loops. The Pacific food system is anything but closed, and perhaps more influenced by external drivers, such global economic fluctuations and climate change. We also acknowledge that food systems are messy, and not amenable to design by external agents. Nevertheless, the idea of a food system resonates with policy makers and others that can influence the course of food security in the region in ways that 'nutrition sensitive agriculture', 'resilience', 'sustainability', and other framings do not.

The food system framing has both analytical and normative functions. Our ambition is to provide a strong integrated body of evidence to underpin and shape political narratives along pathways to change. This ambition will require translation of analytical findings and creation of strong simplifying narratives that capture both the importance and urgency of the problem. This approach is necessary because an important principle of system-based problem framing is that aspects cannot be reduced to only working on 'simple' technical subsets, such as, for example, plant disease control or aquaculture productivity. Note, this framing does not critique the importance of technical research within food systems – specific issues need to be parsed and resolved, but if the food and nutrition problem is framed as a food system then more and different research and policy is needed. As a consequence, the research process has to designed in ways that draw in the disciplines required, but also others to co-develop the research questions. Ad hoc Working Groups, such as those managed by the National Center for Ecological Analysis and Synthesis (NCEAS) (https://www.nceas.ucsb.edu/) offer a model to be adapted to a more TDR context.

Rural market in Malaita Province, Solomon Islands

Judged by the complex multi-scale nature of Pacific fisheries and food systems and our ambition to contribute to nudging them toward better serving the people of the region, we may be doing TDR. We are inspired to contribute to an important and urgent problem, we partner with a range of practitioners and stakeholders, we 'do' development as well as research, we use participatory methods, we have a unifying set of research questions and development outcome targets, and interact across a range of disciplines. But knowing this does not adequately portray how we are set up to work.

The program employs many modes of working. We do narrow disciplinary research on, for example, trade, fisheries management, and nutrition. In contrast, understanding and intervening in local food environments to influence the decisions rural people make about the food they acquire and consume requires participatory

“Trying to avoid a repetition of past failures in supporting Indigenous people to achieve self-determinism through economic independence requires a framing to provide a better definition of the problem and to learn from past and current successes”

modes of enquiry. Community engagement and catalysing the development of community-based fisheries plans is highly participatory, and in many respects is more ‘development’ than RforD. Across it all we use a mixed methods approach to monitoring and evaluation that employs both quantitative evaluation of trends in fisheries and ethnographic techniques to understanding changes in peoples’ lives.

The idea that there is a spectrum from DR to TDR seems inadequate – it needs a few more dimensions to adequately map modes of enquiry onto these labels. Like a Lego house with different coloured blocks, we are a composite of different disciplines brought together to contribute to making progress with a deep societal problem. The important point is that all these approaches sit comfortably at the table and, together, they describe the nature of our TDR program.

FRAMING INDIGENOUS ECONOMIC DEVELOPMENT IN THE NORTHERN TERRITORY, AUSTRALIA

Indigenous economic development in remote Australia, being as it is squarely situated within the global north, is rarely framed within a development context - neither in the literature nor within state or federal government policy and programs. But it is as equally complex and contingent as food and nutrition security in the Pacific. It is similarly molded by many forces – cultural determinism, colonial legacy, entrenched racism, decades of policy experimentation and failure, and the remoteness and poor resourcing of outback Australia that challenges business and enterprise viability. Trying to avoid a repetition of past failures in supporting Indigenous people to achieve self-determinism through economic independence requires a framing to provide a better definition of the problem and to learn from past and current successes. Such a conceptual framing will help create narratives for change that bridge and help align cultural determinism within the ever shifting political and ideological positions of the governments of the day.

Our work with the Northern Territory Government sought to create a framework that captured the learnings of past work, categorize these learnings into key themes, and translate key success factors within those themes into a conceptual framing that guided our program of work. It directed us to focus on what turned out to be nine success factors across the three key themes of Culture, Business and Markets (Fleming 2015). Does this look like IDR/TDR? Perhaps so, we certainly worked across academic disciplines and with multiple stakeholders, but it emerged without direct reference to the transdisciplinary or development literature. Similar to the food system framing in the Pacific, our approach offered a pragmatic, problem-based process that articulated a way of working together to address the complexity and contestability of Indigenous economic development in remote Australia. As might be anticipated, it was not easy to work in this manner. It required from us an openness, even a strong will, to doing things differently, to work outside of our discipline, practice constant cycles of reflectivity and reflexivity, embrace the messiness and often tension of multiple and diverse partnerships, take a longer-term view, and, often the most difficult for some, give voice and control to Indigenous people.

Our approach worked well for us in the Northern Territory and it continues to do so today, under new stewardship. Why? Because we were able to deliver against both government and Indigenous interests and simultaneously harness the drivers, motivations and grand ambitions of each. For a period of time we were given the opportunity to work across government and with external researchers, stakeholders and beneficiaries. We were able to muster the funds for the traditionally unfundable. We were able to deliver against the policy of the day - focused on Indigenous job creation – by co-creating culturally-aligned (that is, meaningful and enriching) work opportunities for young Indigenous men and women. Our work was both transdisciplinary (in that excursions into other’s disciplines informed and altered our outlook and work) and strove to shift towards the paradigm of people, rather than the technically-centred paradigm of things that had repeatedly led to our past failures. Clearly, in the end, a paradigm of adaptive and participatory pluralism is most likely to lead to the kind of knowledge generation that best informs pathways for change in people’s lives. The key lies within each of us as self-aware, reflexive and adaptive researchers, as much as the typologies of RforD.

So perhaps the issue is not whether, or what sort of, interdisciplinarity discourse best offers a pathway to tackling complex and important and urgent problems, but rather a question of how we can better foster these skills and attitudes in academia. This speaks directly to Robert Chambers’ major contribution to development theory and practice. Chambers’ central thesis in promoting participatory methods is that practitioners have been much of the problem in past failures, and so ‘it is through change in us that much of the solution must be sought’ (1997). Chambers is all about people-centred approaches, and sought to shift practitioners and development institutions to think and act more within the paradigm of people rather than things – namely, to shift from a development process focused on blueprints for action (corresponding with the ‘things’ paradigm) to a focus on co-learning in action (corresponding with the ‘people’ paradigm) (Chambers 2010).

Chambers maintains an inspiring optimism for the future - in 2012 he claimed that ‘it is a great time to be alive’, stating that his confidence lies in the capacity of a globally connected body of self-aware, reflexive and adaptive practitioners to change the world of development, one small change at a time (Chambers 2012). Notice the focus on personal attributes, capabilities and approaches, rather than reference to interdisciplinary framings. You could argue that his position points to the former leading naturally to embrace the latter, that is, a self-aware, reflexive and adaptive practitioner (and by extension RforD practitioner) will value and be well equipped to pursue transdisciplinary approaches. So an effective practitioner has in their intellectual DNA a propensity for co-learning and being comfortable with emergence, unpredictability, and other elements of complexity, and for co-participation and an ability to foster enabling and empowering partnerships needed for participatory knowledge generation. Surely this is describing an integrated, ground-up mode of RforD that naturally emerges from a people-centred paradigm?

Bunug Galaminda sampling oysters, Goulburn Island, Australia

INTERDISCIPLINARITY INTO POLICY

If IDR/TDR is a tough gig, then translating insights into policy and other outcomes requires different relationships and an even greater flexibility and adaptability. The interface between research and development outcomes is arguably even more challenging and certainly more important than boundaries among research disciplines. If addressing important and urgent problems are among the defining characteristics of TDR, then greater attention needs to be paid to the ways in which research is translated into outcomes and impacts, and by whom. In our view inadequate progress is being made on this research frontier, despite the fact that the ambitions of all RforD to have an impact on the world rest upon translating research and multiplying its outcomes to have broad-scale impact (see also Pohl et al. 2017 and others).

Interdisciplinary research is often touted as providing solutions to complex societal problems, but IDR does not provide (‘deliver’, ‘resolve’ etc) complex societal problems; it is an ingredient in a process that may become a solution when implemented. The solution is

“ Improving the public health outcomes from the Pacific region’s dysfunctional food systems may be thought of as a long-term complex issue requiring whole-of-government approaches. ”

delivered by a range of actors influencing and convincing a much broader constituency that interprets, manipulates, subverts and translates the research through a highly political process.

In translating research to outcomes and impacts, the substance of the research may be critical (e.g. managing Newcastle disease in African chickens or solving a hatchery bottleneck in aquaculture production). Alternatively, its utility may be less about quality than its delivery, timeliness, whether it can be incorporated into existing narratives, the credibility of the researchers as individuals, and so forth. Sometimes, for example in fisheries management, it can provide a critical external circuit breaker that ‘allows’ or legitimizes an unpopular change to fishing practices. The important point is that the translation process changes the rules for judging quality and credibility. Confronting as it may be, ‘poor research’ may be useful and even transformational.

How knowledge is created and by whom is an important dimension of this translation process. The language of a lot of IDR infers a handover or delivery of knowledge, of the baton being passed. As if knowledge is created separately from its translation and application. In the medical domain, much translational research is of this type – the language is ‘bench to bedside and bedside to population’. The metaphor of a pathway suggests a linear progression toward ‘next users’ and then ‘end users’. In our work on community-based fisheries, the world is more complex than that. As in other arenas of rural development, we use participatory action research modalities of learning, in which we seek to broker and catalyse change with communities. The CGIAR Centre WorldFish coined the phrase ‘research in development’ to capture this process of co-learning by doing (Douthwaite et al. 2017 and references therein).

INTERDISCIPLINARITY IN POLICY

Problems that require IDR often need cross-sectorial institutions and engagement in policy. Analogous problems of language, priority and values are as evident. Public sector agencies are mandated to implement government policy and operational agendas. For line agencies like Agriculture or Health, this traditionally sees them focused on their core functions, such as improving production and managing disease. Adding the need to make progress in complex cross-sectoral issues (e.g. climate adaptation, public health crises, disaster management) to their overloaded work plans is taxing.

An increasing trend in many countries, including Australia, is to promote ‘whole of government’ approaches to tackle complex problems. The Australian Public Service Commission (https://www.apsc.gov.au) defines ‘whole-of-government’ as “… public service agencies working across portfolio boundaries to achieve a shared goal and an integrated government response to particular issues …” Operationally, this requires agencies to execute both the roles they are accountable for in the short-term and engage with long-term strategic issues.

Improving the public health outcomes from the Pacific region’s dysfunctional food systems, for example, may be thought of as a long-term complex issue requiring whole-of-government approaches. This is easier said than done, however, as almost all agencies are under-resourced and already hard pressed to fulfil their portfolio obligations. In all jurisdictions, even making policies not incoherent among agencies is a challenge, let alone making them coherent and integrated. The classic examples come from conflicts between agricultural trade and health policies in the region (e.g. Thow et al. 2011). Attempts to address climate change in the region offer glimpses of the pressure that would be placed on over-stretched public servants if they were required to step back and tackle the many dimensions of food security.

We speculate that a careful review of the literature (as distinct from this essay) would conclude that there has been considerable highly impactful disciplinary and multidisciplinary agricultural RforD on complex problems of great urgency. The critical point is that it needs to be fit-for-purpose. Such research would routinely include communities, national policy makers and development partners in defining problems, co-learning and seeking to make things better. Whether such projects identified as being interdisciplinary is unimportant; it is just good RforD. Alternatively, it could be very narrow disciplinary research that targets a critical technical problem within a broader program of work (e.g. historic attempts to support Indigenous aquaculture in remote Australia). Poor transdisciplinary research is no more likely to yield credible and socially legitimate knowledge than narrower framings of research, good or bad.

PRACTITIONERS

At the more impactful end of the IDR spectrum (and overlapping with TDR), practitioners and others outside the traditional domain of science are drawn in to co-create knowledge. This may be an end into itself, to bring fresh insight, and/or it could represent the beginnings of an articulated impact pathway. In the absence of clear impact pathways, it is often unclear what these ‘practitioners’ bring to the table, and the degree to which they add legitimacy to the process. To a greater or lesser extent, inclusion of practitioners beyond symbolic participation may require abandoning disciplinary science.

Often, scholarly disciplines are well-differentiated but non-academics are lumped as ‘practitioners’ or ‘stakeholders’ – their roles left unclear beyond providing more effective problem definition and ‘legitimacy’. These idealized ambassadors of the real world are, in effect, co-opted into a process owned by researchers.

The lack of differentiation of non-academics in IDR perhaps reflects its research-oriented roots in addressing complex problems rather than complex, important and urgent problems. There does not seem to be as much cross-pollination between the IDR/TDR literature and the RforD literature, which pays considerable attention to articulating impact pathways for translating research output to outcomes and eventually development impacts.

Inclusion of practitioners in projects will increase ownership and is an important step, but scaling up learning to more jurisdictions or different contexts requires a different sort of integration. Practitioners bring perspectives and voice to RforD projects but there remain problems of representation and legitimacy. Typically,

NT Fisheres assisting with oyster grading on Goulburn Island, Australia

those that engage in RforD projects are privileged, fluent in the mother tongue of the researchers (usually English), and more able to capitalize on opportunity. These people may become gatekeepers and barriers to legitimacy, denying voice to, for example, women, the landless and others who traditionally may not enjoy full participation and benefits from agricultural RforD.

SIMPLIFYING NARRATIVES

As we move into the realm of outcomes and development impacts, two related processes come into tension. First, simplifying narratives that capture the essence of research findings and the promise they hold for progress need to be articulated to build a political constituency for change. Narratives built on single technologies and solutions are too narrow for complex and messy problems. Taken too far, the ‘simplifying’ part of the narrative becomes a silver bullet (e.g. cash transfers, insurance, marine protected areas, biofortification etc etc). Almost all ‘solutions’ need, in the end, to be local and therefore contextualized to places, values and needs. As a counterweight, if translation narratives become too complex, too full of ‘scholarship’ and nuance, then they fail to grab and hold political momentum. In fisheries, maximum sustainable yield narratives usually fall into this category, particularly in the developing world.

Gail Ngalwungirr processing her sea cucumber harvest

TRYING TO MOVE FORWARD

Unsurprisingly, in our view, there are no simple rubrics that simplify the profound challenges of doing research of the type needed to address complex and urgent problems, and translating that into policy and then development outcomes. Our experience is that impactful research requires longer horizons, is messier and demands more reflexivity and greater adaptability in activities and intermediate goals than many donors would like.

The Australian Centre for International Research (ACIAR) champions partnership, shared problem/solution development, capacity development and long-term engagement in its approach to project development and implementation. These principles have been in ACIAR's DNA for decades yet, interestingly, it does not explicitly identify this mode of research as interdisciplinary. Similarly, the CGIAR 2016-2030 Strategic Results Framework mentions 'interdisciplinary' once, and in passing. Yet interdisciplinary principles and modes of working are deeply embedded in the research programmes of the CGIAR. Neither document mentions transdisciplinarity.

On one hand, typologies of agricultural RforD may prompt more deliberate reflection on project design and the degree of fit to the problem addressed. Belcher et al. (2015) provide important insights into criteria for evaluating research quality in a TDR context, including the very important criteria of legitimacy, credibility and effectiveness. Agricultural RforD may be seen as a field or sub-class of research that contributes to complex and important problems in the relationship between nature and society. As befitting the subject, existing typologies of interdisciplinarity are complex and research driven, so do not provide a basis for reflection for those not interested in interdisciplinarity per se, but who just want to think more deeply about how they do their research and how it can better contribute to societal problems (but see McNeill et al. 2006, Pohl et al. 2017).

On the other hand, perhaps the labels are not necessary in order to fund and implement impactful agricultural RforD. It is tempting to think that Chambers, Ellis, Conway, and other giants of 20th Century rural development science and practice would have seen RforD that is creative, grounded, integrative, reflexive, and alert to power as being just 'business as usual' – distinguished as good or bad. The rest of us might see it as the standard to aspire to, irrespective of what it is called. In the end we are all beginners and to quote Thomas Hobbes (as cited in Medawar 1977), 'there can be no contentment but in proceeding'.

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Pulses policy project team visiting a pulses farm in the district Fateh Jang, near Islamabad, Pakistan.

ANALYTICAL METHODS FOR ECONOMIC AND POLICY ANALYSIS IN ACIAR'S POLICY RESEARCH

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INTRODUCTION

Food is one of human kind's most basic needs, and according to Article 25 of the Universal Declaration of Human Rights of the United Nations it is a fundamental human right. Human development, economic development, peace and security all depend on nations being food secure. The global research community has recognised the important role food insecurity and under-nutrition plays in creating and maintaining poverty traps, with maternal and child under-nutrition identified as the primary pathway by which poverty is transmitted from one generation to the next. Multiple studies link childhood under-nutrition with reduced earning potential due to diminished adult worker productivity. The economic costs of micronutrient deficiencies are considerable, reducing gross domestic product (GDP) by 2–3% in many low-income countries (IFPRI 2014).

Policies that support sustained growth in food systems (from supply through to consumption) are critical drivers for inclusive economic development and for ensuring resilience. The United Nations has set zero hunger (ensuring access to safe, nutritious and sufficient food for all and eliminating all forms of malnutrition) as the second Sustainable Development Goal (SDG) of the 2030 Agenda. Attainment of this SDG depends largely on – and contributes to – the achievement of the other goals of the 2030 Agenda: ending poverty, improving health, education, gender equality and access to clean water and sanitation, decent work; reduced inequality; and peace and justice, to name a few. Increasing population, changing dietary habits and tastes, and changing climate will make achieving the goal of food and nutritional security more difficult.

Achieving the objectives of food and nutritional security requires addressing a host of issues including an efficient and more productive agriculture sector. The sector will need to pay greater attention for environmental concerns, especially when faced with limited natural resources such as water and issues of greenhouse emissions. This will be possible only by adopting more efficient methods and innovative agricultural practices. While increasing agriculture production can help in producing more food, it might not be enough for achieving food and nutritional security at different scales. This is because food and nutritional security is a complex phenomenon of multiple factors and issues that cannot be solved by just one sector or institution.

Evidence based policies, political commitment and social participation in policy processes are needed to create an enabling environment for resolving these issues and delivering food and nutrition security. Policy research can lead to improvements in policies and institutions (or preventing adoption of poor policies and institutions), or it can contribute to the awareness and understanding on the part of policy makers. Any impact-oriented policy

> "... maternal & child under-nutrition identified as the primary pathway by which poverty is transmitted from one generation to the next."

research must have one or more of these effects. Thus, the process of the research and the interactions with policy makers—both during and after the research— are crucial determinants of the impact of the research.

Though the principal focus of ACIAR investment has been on biophysical research, for many years it has supported research projects with varying degrees of policy analysis and communication. In the past five years ACIAR developed and commissioned about two dozen agricultural policy projects in about a dozen countries in Asia and the Pacific. The key research areas covered by these policy projects include agriculture investment, markets and trade, water management, agriculture and land use, food security and climate change. The methods used for economic and policy analyses and engagement with policy makers varied in different projects and in different countries, as did the policy impact. Due to the complex and multidisciplinary nature of the research questions, they required a wide variety of analytical approaches and modelling tools including mathematical modelling, cost benefit analysis, econometric modelling, computable generable equilibrium (CGE) and partial equilibrium (PE) modelling, non-market valuation and bio-economic and hydro-economic modelling. These analyses were conducted by a variety of staff members from various institutions and backgrounds including early career researchers, mid-level scientists and economists and distinguished academics.

This paper describes the relevance of policy research and policy engagement, the increasing focus on policy impact, a variety of common research tools that are effective in the field, the challenges and mechanisms by which policy is influenced by evidence from research, and the implications for future policy research tools. Section 2 reviews why agricultural policy research is needed. Section 3 outlines ACIAR's policy research and engagement approaches. Section 4 outlines the commonly used methods for policy analysis and provides examples of where these methods have been used within ACIAR projects. Reflections on lessons learnt to improve research methods and their effectiveness for maximum policy impact are summarised in the conclusion.

NEED FOR & AREAS OF AGRICULTURAL POLICY RESEARCH

Policy research is a skilful process leading to output and outcomes. The process is a set of activities to perform and outputs to produce. The outputs include documented knowledge about an issue, and about ways to solve the problem, combined with carefully reasoned recommendations for action (Majchrzak and Markus 2014). The outcomes of policy research may be a change in policy or institution, the prevention of a negative change to policy or institution, or a change in behaviour of policy makers. Policy research that does not lead to direct policy changes outcomes may still have value. Therefore, policy research must involve using evidence to understand the causes and consequences of problems, i.e. the advantages and disadvantages and associated risks (Majchrzak and Markus 2014). The process of undertaking the research, and the interactions with policy makers (both during and after the research), are crucial determinants of the impact of the research.

Bad policy not only stifles growth but can lead to a substantial fall in output. One example is the nature of the implementation of land reform policies in Zimbabwe. Another example, closer to home, is the Australian ban on live cattle exports to Indonesia in 2011 (which was reversed after one month). How do poor policy decisions come about? One reason is poor data, in which the policy makers do not have information on the likely effects. Another is the short time horizon, in which the long-term effects are not given enough consideration. Another cause is ignoring inter-sectoral or commodity substitution effects or unexpected impacts of upstream decisions on downstream players in the value chain. Finally, there are market effects, for example where a technology induced increase in production leads to a fall in output prices, possibly making agriculture producers worse off. Sound policy analysis is needed in these circumstances so direct and indirect effects can be duly estimated and considered.

Governments often identify improved agricultural productivity and efficiency as key policy objectives. However, small losses in efficiency and productivity might be accepted when the policy actions are expected to result in significant improvements in income distribution, employment, food security or exports. When making these trade-offs, policy makers form value judgments, explicitly or implicitly, about the relative worth of different objectives.

Project consultation with farm families, Pakistan.

Trade-offs arise because of constraints in the economic system including limited resources and production capacity, cost of inputs and demand for commodities. Trade-offs also arise when some countries restrict import or export of certain commodities or adopt other agriculture policies (such as subsidies on water and energy) to address domestic food security concerns and to improve income and livelihood of farmers. For example, in Pakistan, policies on wheat (output) subsidy and pulses export tax had focussed on specific sectional interests without considering impact on other sectors.

In many countries, the policies of the non-agricultural sectors impose indirect benefits and costs on agriculture. Similarly, the development of the agricultural sector can impact other sectors, including the environment. Many of these inter-sectoral implications are policy driven, for example, subsidies for domestic fertiliser, energy and water combined with a range of import and export regulations and taxes. Sometimes, governments aim to change farmers' behaviour (within socio-economic and political environment in which they operate) by providing them financial incentive to increase their income and family well-being and reduce any risk or by imposing some regulations for sustainable use of natural resources. For consumers, governments aim to increase their income and wellbeing and food security. For example, through social protection programs which exist in many developing countries though of varying nature including social assistance, social insurance and public works programs (Slater and McCord 2009).

Governments in emerging economies generally have broad objectives for the agricultural sector (Monke and Pearson 1989). Important policy objectives include improving agricultural productivity and efficiency, raising farm household income and its distribution, employment, reducing poverty and hunger, increasing food and nutritional security and promoting sustainable use of natural resources. However, as discussed earlier, there are often trade-offs between these objectives. Broadly therefore, the policy analysts' role is to help policy makers navigate these trade-offs. It is also essential for the policy analysts to have ongoing interaction with policy makers in the design of the policy analysis and to develop explicit plans for disseminating the results of research to the full set of policy makers and stakeholders.

In some cases, policy formulation can take place even before the research findings or results are published. In other cases, no economic or policy analysis is done for policy decision making. For example, in Pakistan, the Prime Minister recently banned construction of housing schemes on agricultural lands in Punjab province and it is not clear whether any substantial policy research examined the likely impacts. Often, policy-development processes do not follow publication of ideas in the literature particularly closely. An example is the persistence of price-stabilisation schemes in many countries despite evidence of resulting welfare losses. Clearly it is difficult to reverse poor policies if they are to the advantage of influential stakeholders. Timeliness of policy analysis is an issue: much academic analysis lags behind policy action. Even where rigorous evidence-based policy analysis has been undertaken, policy makers might not take advantage of the results. Sometimes, insufficient engagement by researchers with policy makers leads to analysis which is not adequately framed in the current policy context and environment.

ACIAR POLICY RESEARCH & ENGAGEMENT APPROACHES

ACIAR's emphasis on impact leads to the need to show potential benefits in the development of all new policy projects (including biophysical, social and economic benefits). Thus, researchers must not only select effective analytical methods (see next section) but also position studies more strategically and interact with policy makers for maximum impact, rather than focusing on analytical results and publications alone. The ways in which policy research has an impact are likely to vary considerably between countries. Sometime this is because of different political set ups and policy making processes while in other cases it is due to lack of skills of local researchers and/or lack of capability of policy makers. Thus, many ACIAR policy projects emphasise capacity building for policy makers and for researchers. For example, a project on payment for environmental services in Lao PDR organised training courses for the local researchers, policy makers and other stakeholders on how to estimate cost functions to improve the natural environment and derive demand function or value of the environment.

ACIAR recognises that, unlike some biophysical research, it is difficult to lay down a prescription for policy research. This is because most policy research does not use controlled experiments, and the complexity of the policy formulation and implementation process. A crucial aspect of policy research is how it engages policy makers and the way in which it is implemented. To ensure that the policy research has real impacts, in many cases projects include input from policy practitioners to ensure that the project results are meaningful for policy makers and decisions makers. It has been essential that, early in policy projects, strong connections with policy makers and other stakeholders are established. Most of these projects form advisory groups, councils or boards consisting of experienced people from different backgrounds including policy makers (not necessarily economists, policy modellers or research analysts). These advisers require an understanding of evidence-based policy making and how policy formulation occurs in practice. Engagement with policy makers also requires a practical communication strategy and plan. Policy briefs are often effective, and ACIAR has developed a guideline for such briefs (see ACIAR projects: Assessing farmer responses to climate change – adjustment policy options - ADP/2011/039; Sustainable and resilient farming systems intensification in the Eastern Gangetic Plains - CSE/2011/077).

COMMONLY USED METHODS FOR POLICY ANALYSIS

The International Food Policy Research Institute's (IFPRI's) Food Security Portal lists several useful policy analysis tools. These tools can be used to assess the impact of changes in world prices, production, exchange rates, tariffs and export taxes and subsidies on domestic production and consumption, imports, domestic prices, producer and consumer welfare, and tariff revenues. These tools provide a useful first indication of what to expect from an external or domestic shock or a policy change. However, the analyses can be limited because they often assume there is no interaction between commodities or sectors, and domestic and imported goods are perfect substitutes. For this reason, if initial estimates indicate substantial interactions, more sophisticated modelling is required. These more sophisticated models are the focus of the remainder of this section which draws on several ACIAR policy focussed projects.

Vanzetti et al. (2017a) lay the theoretical foundation of modelling as a tool that can be used to inform evidence-based policy-making. When choosing the type of model to use for evidence-based policy analysis, there are a number of issues that should be considered including data requirements and availability; institutional capacity to develop, maintain and apply models; and conceptual issues when choosing the type of model to use. We provide further detail below on several conceptual issues that should be considered when choosing a modelling tool, and where they have been used in ACIAR policy projects.

Partial versus general equilibrium

Partial equilibrium (PE) models focus on one commodity or a subset of commodities rather than the whole economy. This allows greater policy detail and is most suitable where the commodity or sector does not have significant influence on the whole economy. PE models do well when the shocks are sector specific, but not so well when reforms affect both agriculture and non-agricultural sectors (Hertel 1992). Typically, PE models do not include factor markets. Hence, the results may be overstated because interactions with other sectors are ignored.

A number of ACIAR projects have developed or adapted PE models for policy analysis. A PE model called Vietnam Agricultural Sector and Trade model (VAST), was developed for several policy research questions, such as rural-urban migration and Vietnamese agriculture (Brennan et al. 2013). The analysis shows the movement of labour from rural to urban areas may be beneficial for consumers and have only a limited impact on producers. The analysis also shows that migration is unlikely to have a significant adverse impact on prices and questions the Government policy of restricting migration and justifying it on the grounds of food security. A PE of Pakistan's cropping sector was developed as part of a ACIAR project (Economic analysis of policies affecting pulses in Pakistan - ADP/2016/043) to analyse the economic welfare impacts of various changes in domestic and trade policies (Vanzetti 2017b). The project has made a significant contribution to understanding the policies affecting pulses production in Pakistan and how they can be reformed to promote pulses production and trade in Pakistan. The extent to which the policy recommendations are applied will only be fully understood through time. However, the project has already had some impact on policy reform in Pakistan. For example, there is evidence of increased investment in pulses research development and extension as a result of this project and a change in thinking regarding the Government's role in encouraging pulses production. Policy researchers in Vietnam and Pakistan have been trained in these respective tools so they can be used for policy analysis beyond the life of the ACIAR projects.

Earlier an ACIAR project in Lao PDR (Effective implementation of payments for environmental services in Lao PDR - FST/2011/003) used non-market evaluation techniques 'Choice Modelling' to estimate cost of improving environment and its associated benefits for the residents of Vientiane and international visitors. The project mimicked market principles through the estimation of demand for environmental services and the costs of supplying environmental services and linked supply with demand and ensured that payment for environmental services (PES) schemes generate net benefits to the wider community through the setting of prices for services that equate supply with demand. The project has had impact through its capacity development strategy by exposing staff and students of a local university, government officials and the staff of NGOs to new concepts both in theory and practice. 'Learning-by-doing' played a key role in expanding skill sets and policy recommendations made under the project were considered by the government. ACIAR also commissioned two projects earlier in China to investigate the sustainability and cost-effectiveness of the Program for Conversion of Cropland to Forests and Grassland (CCFGP – also known as the Grain for Green Program) and how to improve the efficiency of land-use change in China (ADP/2002/021; ADP/2007/055). These projects with their partial analyses helped countries in building their capability in policy formulation and implementation, particularly the latter which had some useful policy impact.

By contrast, general equilibrium CGE models cover the whole economy at varying degrees of detail. The number of sectors may range from one or two to more than 100. Likewise, the number of consumers (households) may range from one to thousands. CGE models contain various constraints, such as expenditure cannot exceed incomes, and employment cannot exceed available labour, etc. GE models have a number of drawbacks, such as lack of detail on particular policies or sectors, or specific functional forms. They are also difficult to learn to use and implement. Interpreting the results can also be difficult for policymakers.

An ACIAR project in India (Capturing the potential for greenhouse gas offsets in Indian agriculture - ADP/2010/008) used IFPRI's IMPACT model and Monash University's CGE model. The IMPACT model was used to examine the impact of alternate agriculture and irrigation management practices on greenhouse emissions while the CGE model estimated the impact of subsidies on agriculture production, employment and GDP. Policy impacts were facilitated through early formation of an Advisory Group to advise the project on its aims and objectives and overall findings. The project consisted of various analytical components and its analytical rigour would have strengthened if there was more explicit interaction of all these components and there was linkage between the subsidised fertiliser use and greenhouse emissions and impact on sectoral/national productivity and employment. However, due to varying scales and lack of appropriate data sets it could not be done.

Deterministic versus stochastic

In deterministic models, the output is fully determined by the parameter values and initial conditions of the model. Stochastic models include elements of randomness or uncertainty, such as prices, crop yields which are influenced by rainfall, pests and other conditions. Most models are deterministic, but stochastic models may be useful where storage is involved, when the aim is to make forecasts, or when the value of specific parameters is unknown. Sensitivity analysis may involve stochastic simulation.

An example of a stochastic model developed within ACIAR policy research is a model called Bioeconomic model of Reservoir Aquaculture – Vietnam Operations (BRAVO). An early deterministic version of BRAVO was used by Petersen et al. (2007) to highlight issues of development importance of reservoir aquaculture in Vietnam. Then stochastic version was applied by Petersen and Schilizzi (2010) to consider the impact of price and yield risk on the level and riskiness of expected net revenue of these reservoirs. BRAVO was developed and used in association with policy makers.

Structure and extent of coverage

Where trade is involved, it is useful for a model to cover the whole world, although the rest of the world apart from the focus country may be aggregated into one region. For example, the partial equilibrium model of Pakistan's cropping sector described earlier was developed to include the 11 countries with greatest trade in pulses (one of which being Pakistan) and a 12th region being the rest of the world aggregated. At the other extreme, some models cover 140 countries with each country treated as a single entity. For some purposes, it is useful to divide a country up into several regions. The limitation here is often availability of economic data, which tends to be only collected at a national level.

Dynamic versus comparative static

Comparative static models have no time dimension and are useful for policy analysis where the time profile is not of interest. The comparison is made between two different states with and without the policy change. The 'with' state assumes the effects of a policy change have worked fully through the economy or system of interest. The elasticities reflect whether the impacts are short run or long run. Where policies are phased in over time, or there is a lagged effect of the policy, dynamic models may be used. One example is climate change where decisions taken now can have an effect decades later. Most models are recursive dynamic, which are solved one period at a time. This implies agents are not looking into the future. The ACIAR project (Assessing farmer responses to climate change – adjustment policy options - ADP/2011/039) modelled the impacts of long run climate change in Vietnam and China using the dynamic agricultural partial equilibrium model (CAPSiM). The project, for example, found that some farmers do respond to extreme weather events by the adoption of a variety of measures (mainly changes in farm management practice rather than engineering measures). Adaptations by farmers even in the short run can make a significant difference to the outcomes in the context of climate change. In the longer term, farmer choices can offset the impacts of climate change by one third to one half. Further, it found that farmers are more likely to take these measures when they have recent experience of a severe weather event, although several household factors and institutional settings affected the choice of adaptation method.

Homogeneous versus heterogeneous products

Homogeneous products are completely substitutable. Historically, agricultural goods such as wheat, rice and sugar were considered homogeneous. This implies that consumers do not differentiate between domestic and imported products, nor between imports from different countries. This approach has fallen out of favour in recent years because of the observation that some countries both import and export the same product. It is now more common to treat goods from different sources as imperfect substitutes (heterogeneous) using the so-called Armington approach. The Armington elasticity allows the user to specify the degree of substitutability or heterogeneity. The Armington approach was used for the Pakistan PE model in the project (Economic analysis of policies affecting pulses in Pakistan - ADP/2016/043), mentioned earlier. The aim of this project was to provide evidence-based economic analysis and advice to policy-makers on policies affecting pulses production in Pakistan. The model included the four main pulses grown in Pakistan and four additional crops that were substitutes in either the consumption or supply of pulses.

Multidisciplinary and multidimensional projects

Considering the complex nature of agriculture policy research issues and the need for input from other disciplines, some ACIAR policy projects were multidisciplinary in nature. For example, a project (Strengthening incentives for improved grassland management in China and Mongolia - ADP/2012/107) needed research into the incentives driving these systems to design more efficient incentive schemes for improved grassland and livestock management. The analysis required understanding of the grassland condition, its carrying capacity for animals, opportunity cost of land use and value of improved grassland. Thus, the project received input from grassland scientists, agricultural economists, bioeconomic modelers and experts in non-markets evaluation. Another project (Promoting sustainable agriculture and agroforestry to replace unproductive land-use in Fiji and Vanuatu - ADP/2012/013) needed identification of different agroforestry systems with varying time dimensions (annual and perennial) and their financial analysis as well as legal analysis of existing policies, laws, land-use plans and land management practices. A team of agriculture economists, land use planners, policy and legal experts contributed to and carried out a comprehensive analysis and helped land use planners and other policy makers. Another project (Improving policies for forest plantations to balance smallholder, industry and environmental needs in Lao PDR and Vietnam - ADP/2014/047) addressed the questions of the current policy arrangements for tree plantation development in Lao and Vietnam and how well they support national forest policy goals. Input was needed from forest experts, forest economists and policy analysts, with capacity in law and value chain analysis. Recognising the value chain approach and its usefulness in policy formulation, one recent ACIAR project (Value chain and policy interventions to accelerate adoption of zero tillage in rice-wheat farming systems across the Indo-Gangetic Plains - CSE/2017/101) investigated how the adoption of zero-till technology (critical for sustainable agriculture production and local environment) can be accelerated as a viable option for farmers across the Indo-Gangetic Plains. The project examined how best to halt the practice of burning crop stubble residues, reduce air pollution and in turn reduce human health impacts, requiring expertise of mechanisation, extension, value chains and policy formulation.

Further, it is to be noted that governments in emerging economies generally have broad objectives for the agricultural sector (Monke and Pearson 1989). Important policy objectives include improving agricultural productivity and efficiency, raising farm household income and its distribution, employment, reducing poverty and hunger, increasing food and nutritional security and promoting sustainable use of natural resources. However, as discussed earlier, there are often trade-offs between these objectives. Broadly therefore, the policy analysts' role is to help policy makers navigate these trade-offs. It is also essential for the policy analysts to have ongoing interaction with policy makers in the design of the policy analysis and to develop explicit plans for disseminating the results of research to the full set of policy makers and stakeholders.

MECHANISMS BY WHICH POLICY IS INFLUENCED BY 'EVIDENCE'

All the above-mentioned projects, sophisticated models and analytical approaches required a well-planned engagement strategy (including early engagement with influential stakeholders and providing relevant empirical evidence based on objective assessment). This strategy must be both within the project so the members from different background and disciplines could frequently interact with and provide input to each other and outside the project with key stakeholders so there is any early buy in and clear ownership and impact of the analyses. However, this strategy or approach may be a necessary condition for policy impact but not sufficient because sometimes some of the best research takes a long time to gain traction.

Policy research can also have value in maintaining the status quo and preventing backsliding. Good economic and policy analysis can have the impact of stopping bad changes, but it will not be an easy task to prove using the ACIAR assessment of impact. This is because often there are other challenges and mechanisms by which policy is influenced by 'evidence'. Gaining policy impact is a major challenge because there may not be enough 'evidence' and furnishing that evidence to key stakeholders may not lead to a positive or desired outcome. There will inevitably be some losers from a policy and distributional concerns can inhibit its implementation (or change in policy from the status quo). Pointing to potential national welfare gains (for example) can be useful, it may not be enough to garner the political support required to implement the policy unless the actual redistribution and facilitation of adjustment is made part of the reform package. Further there are different levels of governments (national level to subnational level and regional level). Before and during the project, it will be useful to identify potential policy impacts and affected parties and stakeholders and seek close involvement with these stakeholders. Identifying the local level as the most appropriate for a policy can create the opportunity for closer stakeholder involvement with policy making (Van Tongeren 2008).

Complexity and uncertainty make policy choices hard even if they are made purely on technical grounds because those with special interests will try to align their demands with the public interest. In such situations, evidence and analysis that is robust and publicly available can serve as an important counterweight to the influence of sectional interests, enabling the wider community to be better informed about what is at stake in interest groups' proposals, and enfranchising those who would bear the costs of implementing them. Therefore, good evidence can ameliorate or 'neutralise' political obstacles and help in implementing an appropriate policy and making reforms more feasible (Banks, 2009). ACIAR project "Economic analysis of policies affecting pulses in Pakistan - ADP/2016/043" is such an example which made a significant contribution to understanding the policies affecting pulses production. The analysis showed how imposing a 35 per cent export tax on pulses and subsidy on wheat procurement affected pulses production and warrants reforming to promote pulses production and trade in Pakistan.

Pastoralist household beneficiaries, Mongolia

Policy maker visit to pastoral communities, Mongola

CONCLUSIONS

Agricultural policy is a complex issue. For example, food insecurity is caused by problems associated with access to and distribution of safe and nutritious food, which is exacerbated by drought, conflict, population growth and poverty. Governments play an important role in facilitating food security. Good public policy influences how people, sectors and institutions interact with each other and provide incentives to improve food security outcomes. An enabling environment has a range of dimensions that policy can influence, including production, distribution, trade and consumption. Public policies are essential because market mechanisms alone cannot provide for all the resources needed for producing, storing and distributing food along the value chain, nor deliver the institutions and regulations required to underpin equitable and safe food systems.

In this paper, we highlight that evidence-based policy analysis can lead to real impacts through early engagement and input from policy makers, researchers and practitioners. The ways in which they are engaged vary considerably between countries and projects. In ACIAR's development policy program, projects generally started with development of an Advisory Committee to guide and assimilate research as it unfolds. An early engagement strategy was planned for both internal as well as external engagement. Frequent internal engagement helped the team members from different background and disciplines to understand and acknowledge contribution everyone made and provided opportunity for others to contribute. While the external engagement strategy gave opportunity to interact with the key stakeholders including resource managers and policy makers to provide any input, it also helped them understand the usefulness of the work and seek ownership of these analyses.

The methods used for economic and policy analyses also vary across projects and countries. Due to the complex and multidisciplinary nature of the projects, a wide variety of analytical approaches and models are required. Choice of methodology depends on the question to be answered, data requirements and availability; institutional capacity to develop, maintain and apply models; and conceptual issues (for example partial vs general equilibrium, deterministic vs stochastic, regional vs global coverage, dynamic versus comparative static, and homogeneous vs heterogeneous products).

The models and approaches used and early engagement with influential stakeholders are a necessary but not sufficient conditions for policy impact because sometimes the best research can take a long time to gain traction. Gaining policy impact is a major challenge and the newly generated evidence (including about welfare impacts) may not be enough for a desired outcome. This is because there will always be some winners and some losers from a policy compared with the status quo. Further there are different levels of governments and it is useful to identify potential policy impacts and affected parties and stakeholders and seek close involvement of these stakeholders. Complexity and uncertainty make policy choices hard even if they are made purely on technical grounds because those with special interests will try to align their demands with the public interest. In such situations, evidence and analysis that is robust and publicly available can serve as an important counterweight to the influence of sectional interests, enabling the wider community to be better informed about what is at stake in interest groups' proposals, and enfranchising those who would bear the costs of implementing them. Therefore, good evidence can ameliorate or 'neutralise' political obstacles and help in implanting an appropriate policy and making reforms more feasible.

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GRAPPLING WITH COLLECTING DATA ON HOUSEHOLD PREFERENCES IN EMERGING ECONOMIES: WHAT ROLE FOR DISCRETE CHOICE EXPERIMENTS?

On the road to community consultations, Lao PDR

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ABSTRACT

In this paper we consider some of the benefits and pitfalls related to using discrete choice experiments to inform decisions about smallholder agriculture in developing countries. The paper draws on two cases – one related to the preferences of smallholder irrigators in south Asia and another concerned with payments for the provision of wildlife diversity by smallholders in Lao PDR.

We explore some of the specific difficulties practitioners may experiences when applying these techniques in a developing country. We find that there is likely to be greater demand for the information that comes from state preference approaches but the challenges require attention. The complexities of data gathering need to be appreciated and the complications associated with offering participants choice, where historically alternatives were not an option, can prove problematic. Some of these challenges will diminish with enhanced technology and taking additional time to condition respondents could also be worthwhile.

INTRODUCTION

Regardless of the overarching political structure, it is often the case in many developing nations that only limited attention is given to the preferences of individual households in policy planning and development. Even in democratic states, substantive power is vested in state agencies to manage smallholder production and related resources. In this instance, farmers, rural households and even urban households are regarded as 'beneficiaries' and the state assumes the role of 'benefactor'. Under these arrangements the preferences of beneficiaries are secondary to the decisions of the state agency.

Whilst this relationship need not be inefficient per se, there is substantial room for a misalignment of supply and demand. This is especially likely to be the case where farmers shift production to new outputs and the state-run supply apparatus is ill-equipped to adapt. For example, in the case of surface water management, state-run agencies usually control the supply of irrigation water against some historic norm based on the productive water requirements of staples like rice and wheat accompanied by some overarching commitment to deliver some water to tail-end users. Efforts by farmers to diversify into other crops can be constrained, since the water requirements of new crops will often not match historic delivery norms.

Similarly, but in a somewhat different vein, households generally place greater emphasis on preserving natural habitat as incomes increase (IBRD 1992) and the shift in household preferences may not align with a more exploitative approach historically supported by the state.

Against that background, there is value in better understanding the preferences of households. More specifically, this information could be used to help state agencies understand where and how tensions might arise and how to use the often limited resources more efficiently. This information might also stimulate discussions about policy reforms that would support more flexible allocation systems.

Economists have spent many decades developing and refining techniques that can be used to generate empirical information about preferences (e.g. Barber et al. 2012). The starting point for most neo-classical economists is that preferences are ultimately revealed through market exchange where both the purchaser and supplier demonstrate the relative value of a good or service through the market price. The theoretical elegance of this approach is that no choice would be made where the costs of the good/service exchanged are greater than benefits. However, markets do not always exist for goods/services and it is in that context that stated preference techniques have emerged as useful tools for adjudging preferences. More specifically, this information can help ensure decisions are made that do not create costs in excess of benefits. Stated preference techniques attempt to create an 'hypothetical market' and then use surveys to elicit the willingness to pay (or accept) from participants. Whilst widely used in developed world contexts (e.g. Hensher et al. 2015), the use of this approach has progressively gained support in developing world environments, including analyses of issues related to smallholder agriculture (see, Hung et al. 2019). For a broader set of developing country examples, refer to Bennett and Birol (2010).

In this short paper we consider some of the benefits and pitfalls related to using discrete choice experiments (a stated preference technique) to inform decisions about smallholder agriculture in developing countries. The paper draws on two cases – one related to the preferences of smallholder irrigators in south Asia to support alternative water charging regimes and another concerned with payments for the provision of wildlife diversity by smallholders in Lao PDR. The paper itself is divided into four additional sections. Section two provides a synopsis of stated preference techniques and summarises some of the general challenges related to these approaches. This section also highlights some of the specific difficulties practitioners may experiences when applying these techniques in a developing country context. Section three presents the first case, where a discrete choice experiment was used to gain insights into the preferences of irrigation farmers in India and Pakistan. The second case is presented in section four and considers the deployment of a discrete choice experiment to elicit the preferences of Lao PDR residents and international tourists for wildlife diversity. Both cases are presented along the lines of contextual factors, the application itself and challenges that emerged. The final section comprises lessons for those contemplating using similar approaches and some brief concluding remarks.

BACKGROUND TO STATED PREFERENCE TECHNIQUES & THE RELATED CHALLENGES

Efficient decision making requires the consideration of total economic value and welfare enhancing decisions require that benefits not be exceeded by cost. Essentially, total economic value comprises use and non-use values and these might be revealed through markets. However, markets for goods/services do not always emerge, can be incomplete or fail. This can arise due to the inability to define tradable property rights or some other institutional constraint. In these circumstances other techniques are required to assist with determining total economic value. Nonmarket valuation techniques, such contingent valuation and choice modelling, are particularly useful in this context and allow the analyst to fill 'gaps' around values.

Economists generally divide techniques for gaining information about preferences and values into two groups – revealed preferences and stated preferences. Revealed preferences are implied though market outcomes and these can be observed directly or imputed indirectly.

As noted earlier, not all goods are exchanged in markets, but this does not render market information completely redundant. Markets that operate 'adjacent' to a non-marketed good can sometimes be used to infer values. For instance, the value of a view of a pristine landscape might not be directly observable but by disaggregating property sale data the premium for such a view could be deduced (see, for instance, Lu 2018).

Somewhat more contentious are values where there is no market information at all, or that which is on hand is considered too limiting. This has spawned stated preference techniques and these initially gained interest from economists in an effort to fill the void of information about the value of changes in the supply of environmental goods (e.g. Mitchell and Carson 1989). Environmental goods, like natural landscapes, are generally acknowledged as offering benefits to humans that can frequently go beyond markets. Individuals and households might value an environmental asset simply by knowing that it exists, even if they never directly make use of that asset

> "Efficient decision making requires the consideration of total economic value and welfare enhancing decisions require that benefits not be exceeded by cost."

(Attfield 1998). Capturing these types of values requires information about non-use values and by-and-large that may not be accessible through market data.

Stated preference techniques can also be useful for testing new products, policies or ideas that have no history of implementation and hence no record of revealed preferences. In this regard stated preferences can help understand the acceptability of different policy or administrative options that have hitherto not been used.

Stated preference techniques aim to 'create' a product or an outcome in the mind of a respondent and then secure information about the relative desirability of that product/outcome. Two general stated preference techniques are commonly used. First, Contingent Valuation technique describes a single product/outcome and then ask people to express how much they are willing to pay for that product/outcome. The product/outcome might have multiple dimensions or attributes but these do not vary across the survey exercise. Second, a set of techniques known as discrete choice experiments have become popular within stated preference approaches. Here, the product/outcome attributes are varied and a respondent is presented with alternatives (usually two or three) from which they must choose one. By varying the attributes systematically, the choice data then expose how individuals are making trade-offs and a value can then be assigned by comparing trade-offs with a monetary attribute in the experiment. If an experiment is conducted without a monetary attribute some information on preferences is still generated but then attributing monetary values for the other attributes becomes more problematic. This is often referred to as Best-Worst Scaling and is gaining popularity with some researchers (e.g. Rigby et al. 2015).

Discrete choice experiments have become increasingly popular as a stated preference approach, in part because it is claimed to do a better job of replicating real markets where individuals make choices between products/outcomes on the basis of different attributes (Hensher et al. 2015). Discrete choice experiments are supported by the strong foundation of random utility theory (McFadden 1986) where the frequency with which an individual chooses one alternative over another is linked to the underlying benefits (i.e. utility) assigned to the alternative.

However, despite its increased use and popularity there remains some scepticism around discrete choice experiments and the values that are derived from the related data. First, 'stated' preference critics tend to query the extent to which stated choices are representative of true behaviour – walking the walk differs from talking the talk. To counter this, practitioners using choice experiments have devoted considerable effort to ensuring respondents are reminded about the importance and relevance of their choices (see, for instance, Bosworth and Taylor 2012). Similar criticisms of the technique have pushed practitioners to ensure that the salience of choices is optimised. More specifically, when designing the choice experiment the practitioner will usually test different attributes with local participants to ensure, as a minimum, (a) they are described in a relevant manner and (b) they do actually pertain to how the respondent contemplates choice. Johnston et al. (2017) extensively discuss contemporary best-practice recommendations for choice experiments.

Second, choice experiments can involve significant cognitive burdens for respondents (see, for example, Rolfe and Bennett 2009). For instance, a well-designed choice experiment will purposely present respondents with choices that 'push' them to confront difficult trade-offs. In simple terms, if respondents face only rudimentary choices (e.g. between a high-priced product with poor features versus a low-priced product with ample features) the data will reveal little about trade-offs. In this case, almost all respondents will choose the latter over the former, providing no information of the relative value of attributes. A successful experiment, in contrast, will present respondents with a mix of attributes, some of which are preferred and others less so. Respondents involved in choice experiments regularly express disquiet about having to make those choices (Bryan and Dolan 2004) and the survey design process usually requires a respondent to make multiple choice tasks sequentially (see, Hensher et al. 2015). The greater the number of attributes and the larger the number of levels, the richer the data; but this comes at the expense of the cognitive burden on respondents.

Third, in part to cater for the cognitive burden related to experiments, designers of choice experiments have sought to use a variety of tools to help participants generate heuristics. For example, videos and visual aids can be used to introduce choice experiments so that respondents understand the setting (e.g. Jaeger et al.

2001). Symbols are also used to help capture the meaning of complex attributes so that participants can more easily assess trade-offs. Clearly, the use of these types of tools is itself the subject of some concern, given the potential for significantly impacting responses (Rizzi et al. 2012).

USING A DISCRETE CHOICE EXPERIMENT TO ILLICIT PREFERENCES FOR WATER CHARGING REGIMES IN IRRIGATION IN SOUTH ASIA

Context

An ACIAR-commissioned project commenced in 2016 with the aim of enhancing understanding of the role and usefulness of participatory irrigation practices in south Asia. Participatory irrigation became popular worldwide in the 1980s as governments sought to find solutions to degraded irrigation infrastructure and the poor performance of many communal irrigation schemes (Crase et al. 2019). The basic tenant of participatory irrigation is that devolution of more control to farmers and away from state irrigation bureaucracies can lead to enhancements, insomuch as farmers (a) have a more intimate understanding of water delivery at the local level and (b) hold stronger incentives to manage the irrigation network judiciously (Asia Development Bank 2012). Despite its intuitive appeal, participatory irrigation has yielded mixed results at best.

In south Asia participatory irrigation has taken on different forms. In India, Water User Associations were created in many state jurisdictions and some functioned well while others failed. In Pakistan Farmer Organisations were developed along similar lines to Water User Associations with the task of managing the smaller components of the irrigation network (e.g. so-called 'minors'). In some instances, a farmer-led hierarchy was also envisaged with Area Water Boards assuming control of larger parts of the irrigation network with representation drawn from Farmer Organisations. Overall, the ambitions of participatory irrigation have not been met but few alternatives are available. In essence, there is a view held by many that there is no going back and that a solution to better participatory irrigation must be found (Suhardiman 2014). State ownership and control of water is characterised by challenges such as free-riding and rent seeking and necessarily prohibits markets from being formed, especially markets for alternative forms of water governance. Thus, in the absence of markets, non-market valuation techniques can assist with establishing values.

Application

Irrigation is under the control of state and provincial governments in India and Pakistan, respectively. Thus, whilst national frameworks exist to support participatory irrigation, the design of local water institutions differs considerably across the region. In some cases, the local irrigation institution will be expected to collect irrigation fees from farmers and then use these monies to support local irrigation maintenance activities. In other cases, the local institution will be assigned responsibility for allocating local labour to maintenance tasks. Enforcement of various water-sharing rules can also be assigned locally. There is limited understanding of farmer preferences in this context and this may inflate inefficiencies.

One of the advantages of the variation in institutional design across jurisdictions is that it creates a setting where a discrete choice experiment can potentially offer different choice scenarios to test for performance improvements. With that in mind, a data collection process was designed for two states in India – Assam and Bihar – and two provinces in Pakistan – Sindh and Punjab. Whilst the initial project had sought to focus primarily on water institutions and the link to agricultural performance, early qualitative work revealed a wide array of local adaptation of state/provincial rules and questions thus arose about how farmers had settled on those designs. Questions also emerged around the extent to which farmers might more willingly embrace participatory irrigation under different charging regimes. Of particular interest was the extent to which retaining monies at the local level would engender greater support and compliance.

A discrete choice experiment was adjudged useful in this regard. Since it seemed incongruous to ask farmers to 'pay' for a change in the way they were charged, a best-worst scaling format was chosen.

An initial scan of regulations across states showed a complex environment. Whilst charging was one part of the institutional apparatus of water user groups other elements were also important. For instance, water charges were not the only component of interest with variations occurring around who made the assessment of charges, how the charges were applied, who imposed sanctions on non-payment, what portion of funds were retained locally and to what extent funds were expected to be used versus labour or state monies.

These attributes were initially tested in a single experiment with farmers but the cognitive burden imposed from the complexity of the experiment proved problematic and it was subsequently divided into two separate discrete choice experiments.

The first experiment focussed primarily on charging regimes and included the basis of charging, assessment method, payment method and collection regimes. The aim of this experiment was to better understand smallholder preferences and then to better align tariff design and collection methods with those preferences.

The second experiment considered a wider range of factors related to the operational modality of water user groups. More specifically, the attributes were the proportion of irrigation fees that would be retained locally, the mechanisms for applying sanctions and the method for maintaining local irrigation infrastructure. The purpose of this experiment was again to increase understanding of smallholder preferences to inform reform around the governance of water with an expectation that any changes that aligned with farmer preferences would be more easily introduced.

Choice experiments require the respondent to treat each choice separately and ideally the respondent cannot refer back to previous choices. Since the design generates a large number of choice sets (36 in this case) the survey was to be applied so that farmers would face a sub-set and the 'blocks' of choice questions would then rotate with respondents so that data was collected across the full array of choice sets. The literacy level of farmers in developing countries needs to be considered when determining how many choice sets to include in each survey. More specifically, the researcher needs to be mindful not to create an excessive cognitive burden for participants.

Practical adjustments to methods

Notwithstanding the extensive references around conducting an effective choice experiment, there are often a number of contextual constraints relative to administering a choice experiment in an emerging economy, such as survey administration mode, available resources, limited literacy levels and weather conditions. Numerous theoretical constrains are also often apparent. The following discusses each of these in more detail.

In terms of contextual constraints, a common conundrum of administering a choice experiment in developing countries is that there is often a trade-off between applying cutting-edge techniques with approaches feasible to the setting at hand.

Community consultation to understand farmers' preferences for different irrigation charging regimes & to develop attributes for the choice experiment, North-East India

For instance, the data collection mode can be limited in emerging countries and leading-edge approaches may not be practical to administer due to constraints around resources/training or cultural and language barriers. In this case, tablets were purchased and a firm specialising in providing mobile data collection platforms was commissioned to transpose the survey and store the data. The data were collected in country via in-person interviews and recorded via the mobile tablets. Notably, the research partners, who had varying levels of experience with choice experiments, administered the data collection. This presented a number of challenges in that extensive training and on-going communication with those collecting the data was required. In addition, the choice experiment had to be developed in a format to facilitate translation into multiple local languages.

The experiment was piloted in Assam, a state in northeast India, to ensure respondents could comprehend the survey and that attributes and levels resonated with respondents. Piloting revealed that in the context of limited literacy, the text used in the survey had to be further simplified and the use of images and graphics was important. It also became apparent that there were challenges with digital survey administration such as batteries running out of charge on devices during data collection and lack of Internet connection at times.

Weather conditions often play a pivotal role in the timing of data collection. In this instance, data gathering commenced in east India as there was a pressing need to avoid the oncoming monsoons.

The administration of choice experiments in emerging countries is also characterised by theoretical challenges. For instance, choice experiments are underpinned by a presumption of stable individual preferences and in this environment surveys are usually completed by a household 'head'. The household 'head' in this region is often a man and the scope for gaining an understanding of more inclusive preferences representing the whole household is a challenge for surveys of this form. In this context, researchers need to make a conscious effort to capture the preferences of groups that are often under-represented, such as women and youth. Recent methodological advances in choice experiments allow the preferences of multiple agents involved in a decision making process to be captured simultaneously.

A debrief following data collection was also particularly revealing. Survey administrators noted that respondents were curious about the choice sets but were also challenged by being asked about their preferences. Put simply, many farmers had never contemplated options of this form and often accepted the status quo as a state of nature beyond their influence. In this regard, the administering teams noted that the choice experiment played a useful educative role but questions remain about the extent to which respondents had well-defined preferences in this context or were developing them in the process. Put simply, it remains an open question as to whether these data can help shape the lowest cost means of encouraging reform of water institutions in these countries.

ESTIMATING THE DEMAND FOR WILDLIFE DIVERSITY PROTECTION IN THE LAO PDR BY MEANS OF A DISCRETE CHOICE EXPERIMENT

Context

The estimation of the demand for wildlife diversity protection was part of an ACIAR-funded project that aimed to design and implement a Payments for Environmental Services (PES) scheme in the Lao PDR . Lao PDR provides habitat for a range of wildlife species that are of global and national conservation significance and classified by the IUCN as endangered and critically endangered. The main threat to wildlife diversity is poaching and associated wildlife trade. The PES scheme was developed to provide environmental services associated with the protection of wildlife diversity in the Phou Chomvoy Provincial Protected Area, a mountainous area located in the Northern Annamite Ranges bordering Vietnam. More specifically, the scheme involves funding local smallholder farmers to act to reduce poaching in the region (Scheufele and Bennett 2019).

Application

The design of a PES scheme involves setting a 'market price' to be paid by those using the environmental service to those who supply the environmental service. This requires the estimation of the extent of demand and supply (Scheufele et al. 2018). A discrete choice experiment was conducted to estimate the demand for wildlife diversity outcomes. The wildlife protection actions, delivered through a comprehensive anti-poaching patrol scheme run by local farmers, were designed to ensure the continued existence of wildlife diversity . The demand was estimated for two buyer groups: the international tourists visiting Lao PDR and the residents of the urban areas of Vientiane City. In a developing country context, it is important to ensure that the identified buyer groups (or population segment for which demand is to be estimated) has sufficient disposable income to extend to the purchase of environmental services. Otherwise, a discrete choice experiment based on a trade-off between non-monetary and monetary attributes is not feasible. For that reason, the survey was restricted to the residents of the urban (and therefore wealthier) parts of Vientiane City.

The survey material included a survey protocol, a questionnaire script to be read by the interviewer, show cards, answer sheets to be filled in by the interviewer, and choice booklets that contained the choice questions. The survey respondents chose between three options with different levels of wildlife protection effort and associated wildlife diversity outcomes. The options were described by five attributes (species diversity; poaching effort level; tourist access; benefitting households located in villages that provide anti-poaching patrols; visa entry fee (for tourists) and household payment through the electricity bill (for Lao residents). The tourist respondents were surveyed at random in the international departure lounge at Wattay Airport in Vientiane City. The residents of Vientiane city were surveyed through face-to-face interviews in their homes using a random sampling strategy. Stratified sampling, which reduces the risk of drawing a sample that is not representative of the population, was not an option due to a lack of maps delineating statistical divisions. For both buyer groups, the surveys were conducted using a pen and paper survey. The survey targeting the resident respondents was presented in Lao, whereas the one targeting the tourists was presented in English. The data were analysed using

Household survey to construct community resource profiles, Lao PDR

mixed logit models. All estimated attribute coefficients were statistically significantly different from zero and had the expected signs. The values so estimated were used along with supply cost information derived from conservation auctions in a pseudo market model to determine price.

Practical adjustments to methods

The discrete choice experiment was designed specifically for a developing country context. It was designed to account for a lack of spatial data on statistical divisions, a lack of professional interviewers and with an eye to culture-specific norms and taboos of respondents and interviewers. Low literacy levels, especially among the resident respondents and limited language capabilities among the interviewers was considered, and a lack of experience with the principles of confidentiality and anonymity - taken for granted by respondents participating in surveys conducted in developed countries – was also taken into account.

The lack of spatial data on statistical divisions was addressed by employing a random sampling approach. This requires a large enough sample to increase the probability of drawing a representative sample. The lack of professional interviewers was overcome through intensive training to ensure appropriate data quality. Special attention was given to communicating the importance of confidentiality and anonymity.

Respondents' expected tendencies of wanting to please the interviewer instead of revealing their true preferences was addressed by maximising the anonymity and confidentiality of the survey process. This was achieved by providing choice booklets and instructing respondents to submit them in a sealed envelope once they made their choices unobserved by the interviewer.

Low literacy levels among the resident respondents and limited English language capabilities among the interviewers and tourist respondents were addressed through the extensive use of images and graphics

Community consultation on the implementation of the PES scheme, Lao PDR

presented in show cards and symbols used in the choice questions. Collectively, these approaches make progress to help defined the economic benefits of the PES under consideration but, nonetheless, these arrangements place some caveats on the data gathered.

LESSONS ABOUT THE USE OF DISCRETE CHOICE EXPERIMENTS & CONCLUDING REMARKS

The case studies presented in this paper highlight a number of priorities to consider when administering choice experiments in low income countries, such as the availability of appropriate and cost-effective modes of data collection, accessing a representative sample, experimental designs sympathetic to cultural-specific norms and limited literacy levels of respondents and interviewers.

Choice experiments require respondents to make trade-offs and this creates a cognitive burden in many cases. That burden can be exacerbated by poor literacy and other pressures, like social norms that encourage yea-saying. The options for dealing with this are often simply not practical in an emerging economy context. Internet surveys, for instance, are claimed to allow participants more time to reflect and can be linked to other resources and also engender a sense of anonymity – such surveys are not accessible in the settings described in the cases. Stratifying samples reduces the risk of bias, but overarching data on which to develop strata are often unavailable. As discussed in section 3, there are also challenges around recruiting an inclusive group of participants i.e. representation of the preferences of women and youth.

Administering choice experiments can be a valuable learning experience and build capacity of researchers, who are often commissioned from educational organisations in country. The extent to which these personnel can be trained to cater for the wide array of challenges while developing a deep understanding of the technique is constrained by project budgets and time.

Overall, the scope for using discrete choice experiments in developing countries is considerable; especially as decision makers increasingly require more knowledge about household preferences. Nonetheless, there are non-trivial issues that need to be considered. Some of these relate to the practicalities of data gathering and the effectiveness of different surveying technologies. These challenges will likely diminish over time with additional upgrades and refinement. For instance, the increasing spread of mobile telephony will facilitate digital data collection, which affords more control of these types of experiments. Improvements in translation using digital devices are also significant in this context.

On the other hand, there are ongoing challenges that relate to how respondents conceptualise and respond to choice tasks. In the case of the choice experiment in south Asia, farm households had only limited exposure to the options presented and whilst this might help engender greater engagement on this topic in the future, the stability of preferences estimated by the technique could be a concern. There is also the challenge of eliciting preferences in contexts where market allocation is historically limited. One future option might involve spending additional time conditioning respondents to the notion of choice more generally and then administering a stated preference survey once respondents have had an opportunity to digest the options. This will likely add cost to the data collection phase but the enhancement in data quality may offset the cost. More generally, levels of education will hopefully improve over time and the concept of making a formal choice in a survey context may become more familiar, making the challenges of asking people to state their preferences less onerous.

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Improved wheat yield and food security from strip till, Bangladesh

ACIAR IMPACT ASSESSMENT PROGRAM, STOCK TAKE ON EFFECTIVENESS AND REFLECTION ON NEW APPROACHES

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ABSTRACT

ACIAR has a long history of impact evaluation and, in the last 30 years, has regularly reported the economic assesments of its research projects and published 96 Ex Post Impact Assessments defining rigorously and effectively the benefits of the research it funds. Traditionally, these assessments had a strong economic focus and used theory based approaches applying economic surplus models to estimate the returns from ACIAR projects. However, Impact Assessments have to mirror the evolving role of research for development within the Agriculture Innovation System and need to evaluate expected and unexpected environmental and social impacts as well as economic returns. A Single evaluation method is not always able to assess these various dimensions and so evaluators are using different frameworks, tools and techniques drawing on quantitative and qualitative data in mixed methods to better capture the results from Agricultural Research for Development interventions. In the last decade ACIAR has incorporated and tested innovative methods in its Impact Assessment program and will continue to do so to better account for its contributions to development impacts in our partner countries and help draw lessons to improve on the effectiveness of future investments.

ACIAR IMPACT ASSESSMENT – A LONG & SUCCESSFUL STORY

ACIAR has a strong culture in the evaluation of its research investments and is a rarity in the Agriculture Research for Development (AR4D) community with its long-term commitment to ex-post impact assessment. Already in 1998, Nairn et al. stated that "ACIAR is an internationally acclaimed pioneer and leader in the development of models in resesearch prioritisation and in the rigourous application of routine ex ante and ex post impact assessment processes" this statement still rings true today with ACIAR ex post impact assessment series being held in high regard both domestically and internationally. Since the late 1980s, ACIAR collaborated with the Consultative Group for International Agricultural Research (CGIAR) to develop and apply impact assessment frameworks. ACIAR's Economic Evaluation Unit (EEU) undertook a number of ex-ante and ex-post assessments starting from 1994. The Impact Assessment Series (IAS) that ACIAR still publishes regularly started in 1998 with the research outputs of a series of projects on Newcastle disease (CIE, 1998). Before 1998, ACIAR undertook impact assessment either to demonstrate the impact of the research it funded, or as a preparation for external reviews. However, by 1998, it was decided that all impact assessments should be undertaken by an external impact assessment specialist rather than in-house and in doing so, ACIAR built the credibility of its IAS and addressed the perception, at the time, that assessment of agriculture projects was seen as ad hoc and partial (Alston et al., 2000 p. 8). Since 1998, ACIAR has published 96 IAS reports. Further to this accountability function, impact assessments contribute to learning within the agency, for our partners and to the broader AR4D community.

As Australia's specialist agricultural research for development agency, ACIAR brokers AR4D partnerships in the Indo-Pacific region that produce knowledge and innovations contributing to sustainable development. Impact assessment is a complex process and there are diverse ways to link research outputs to capacity built, policy change, social impacts and economic returns. The pathway to impact is dependent upon various interactions and networks, knowledge sharing, feedback and adaptation.

Traditionally the impact assessments have had a strong economic focus – applying economic surplus models as a means of estimating returns from agricultural research (Alston et al. 1995). In 2008, Davis et al described the general approach to ex post impact assessments of ACIAR projects. This framework is applied to a project or related cluster of projects (or program) and focuses on the specific causal pathway(s) from research outputs to practice change by next users, and subsequent intermediate and final impacts. Applied well, this economic surplus method is recognised for its transparency and rigour in treating data, variable assumptions, detailing of counterfactual scenarios, the attribution of benefits arising from a project's outputs, and estimating how benefits are shared amongst beneficiaries (for example, consumers and producers) (Alston et al 2000).

Returns estimated from ACIAR's research investments vary. For example, benefit cost ratios in excess of 100:1 attributable to research involving forestry projects in Indonesia (Lindner, 2011), rice production in Laos PDR (Harris, 2011) and pig production in Vietnam (Fisher and Gordon, 2008) have been identified. While other projects subject to impact assessment have been estimated as having negligible or even negative economic returns. As an example, ACIAR investments in mudcrab hatchery technologies in Vietnam (Lindner, 2005), grain drying technologies in Philippines (McLeod et al, 1999), and barramundi fisheries in Papua New Guinea (Fisher, 2010) had low or negative returns. Despite the variation in economic benefits reported, a meta-analysis of IAS results by Lindner et al (2013) using a highly conservative approach, where only benefits identified in the sample of projects subject to impact assessments but all ACIAR project costs were included, estimated a lower-bound benefit-cost ratio of 5:1 from all ACIAR's investments since 1982.

It is important to note that low economic returns from projects do not necessarily mean that projects have been unsuccessful (Pearce, 2010) or that there are no positive impacts arising from the research. This is because there are significant challenges in adequately capturing benefits in economic terms from environmental, social, and policy impacts and capacity building attributable to research, nor is it appropriate in many cases.

Recognising this complexity Davis et al (2008) outlines how assessments of social, environmental and capacity building impacts, not captured in an assessment's economic model, can be described qualitatively in the impact assessment framework. As the intended objectives for agricultural research for development investments has become more explicit in targeting social, environmental, policy impacts and capacity building, more holistic approaches to impact assessment are required.

CURRENT CHALLENGES FOR AR4D IMPACT ASSESSMENT

Impact assessments have to follow the evolving role of research within agricultural knowledge systems. In the past, the prime responsibility of researchers was to develop technologies that were then transferred to farmers via extension agencies. This role has changed with the increasing complexity of the Agriculture Innovation Systems (AIS) and the emergence of the AR4D concept. AR4D is a set of research approaches that aim to contribute directly to the achievement of development targets. In AR4D the use of research outputs and their contribution to development outcomes is as important as the production of research outputs (Thornton et al., 2017). Today AR4D research goes beyond technical solutions and has to consider contemporary issues and opportunities facing agriculture ranging from changes in consumer preferences to climate change.

Similarly ACIAR's new 10 year strategy (ACIAR, 2018) has been framed around building the knowledge base of six high level objectives representing key issues to be addressed by its funding to AR4D: Food security and poverty reduction; better management of natural resources and more effective responses to climate change; improved human nutrition and health; empowerment of women and girls; inclusive agri-food and forestry market chains involving the private sector and building science capacity.

In this dynamic context, the challenges for research project evaluators are to consider the role of different actors in the system, their contributions to the impacts being assessed and the various perspectives of different stakeholders within the AIS (World Bank, 2012). It needs to take into consideration impacts that go beyond expected science and economic performance (Joly et al., 2016). Accordingly, ACIAR's Impact Assessment Program is continuing to adapt the methods that it applies to impact assessments to address these stakeholder perspectives and capture multiple types of impacts.

NEW APPROACHES TO ASSESS AR4D IMPACTS

ACIAR's new strategic objectives require an engagement at a broader system level. Outcomes relating to inclusiveness and empowerment bring an explicit social dimension to the research portfolio. The objective relating to building science capacity implicitly includes network facilitation, as well as knowledge sharing amongst researchers and institutional strengthening. While natural resource management or improved nutrition will not be possible without changes in attitude and practices at community level, at policy level and in industry as intermediate outcomes. As such, there is an increasing need to assist project teams to understand the current baseline conditions and the way to measure these changes, so ACIAR contributions to social, environment, capacity and economic impacts can be understood, described and measured.

> "As Australia's specialist agricultural research for development agency, ACIAR brokers AR4D partnerships in the Indo-Pacific region that produce knowledge and innovations contributing to sustainable development."

This demand for new approaches to the assessment of AR4D is being canvassed in the current impact assessment literature. Van den Berg (2017) discusses the need to invest in evaluation approaches that reflect the holistic approach to sustainable development goals addressing societal, economic and environmental impacts at various scales. Importantly the evidence on impacts needs to be collected over the long term, beyond the life of a project or program, consistent with ACIAR's ex post approach. Assessment frameworks that also look beyond an intervention's specific theory of change to consider the broader system perspective will help to understand the interactions between the intervention and its surrounding environment (Garcia and Zazueta, 2015). These interactions typically lead to unintended impacts that might be missed from a singular assessment of a defined impact pathway.

Experimental methods that construct a control group, such as randomised control trials (RCT) to evaluate development interventions (White, 2013) and quasi-experimental designs are frequently highlighted as effective methods for conducting rigorous impact evaluations. For example, Boubaker et al. (2018) report on the use of RCTs in an agricultural research development project in Tunisia testing technology transfer strategies for smallholder farmers. RCT are thus being used in ex-post impact assessments, but require data to be collected before the start of a project, during the lifetime of the project and after completion of the project. For example, ACIAR is currently funding a project for Inclusive Agricultural Value Chain Financing (AVCF) that is using RCT to assess the impact of different financing models to improve their design. In these cases, the method is applied as part of the research project to test and measure different interventions. If AVCF research is successful, it could be possible for ACIAR to continue collecting RCT data to monitor the evolution of the different financing models for at least 5 years after project completion. Then using this data in combination with the data collected during the life of the project an ex post impact assessment based on RCT method could be undertaken. Such a novel approach differs to the role of ACIAR's ex post impact assessments carried out after the research has been completed. It would require innovative contractual arrangements allowing for data collection after project completion.

Social Network Analysis (SNA) is used in ex post research evaluation to assess how the changes in relationships between actors in a system contribute to the impact of the innovation process. Davila et al. (2016) combined knowledge systems (Cash et al. 2003) and a research and policy in development approach (Overseas Development Institute, 2004) in an Impact Assessment framework. This framework was then used to assess the intermediate and final social and policy impacts of ACIAR projects focusing on aflatoxin reducing technologies and practices in Indonesia.

Rather than experimental methods or SNA, theory based approaches are at the core of ACIAR's evolving Impact Assessment practice. These approaches are intended to link data and its interpretation in terms of cause and effect. It applies theory(ies) of change or impact pathways that explicitly identifies the assumptions about conditions necessary for activities to lead to eventual impacts in communities. For ACIAR such conditions and sequences of actions relate to household and community understanding and engagement, availability

Engaging with community members to understand the impacts of a pig health project, Laos PDR

of appropriate partners to facilitate scale out of research outputs, capacity of actors, markets and access to inputs and markets for the subsequent outputs and policy settings. The 'causal chains' are frequently captured as a narrative or represented diagrammatically. Stern describes this mechanistic focus being dependent on "various starting conditions, supporting factors and predispositions" (Stern et al. 2012 p. 26).

However, it is also important to note that such a mechanistic approach while pragmatic does run the risk of being singular focused on a specific Theory of Change that is linear and sequential. In so doing an assessment does not adequately account for a system's complexity (in which the research intervention is taking place), the non-linear chains of causality, feedback loops, and the dynamic nature of the system. Thus, intended and unintended consequences arising from a research outcome(s) are critical to address (Garcia and Zazueta 2015).

It is increasingly evident that a single evaluation methodology is not able to assess the various dimensions of impacts resulting from AR4D interventions in an innovation system. As such "evaluators must find creative ways to combine different evaluation frameworks, tools and techniques" (Bamberger, 2012) and so evaluators are using so called "mixed-method" approaches to evaluation that systematically integrates two or more evaluation methods drawing on both quantitative and qualitative data (Bamberger, 2000; USAID, 2013). By combining multiple data sources, methods, analyses or theories, evaluators seek to overcome the bias that comes from single informants, single methods, single observer or single theory studies and allow for the use of three or more theories, sources or types of information, or types of analysis to verify and substantiate an assessment.

Recognising the discipline and rigour that continues to be provided by economic methods for quantifying impacts from research, ACIAR continues to complement this economic measurement by testing mixed method approaches and combining theory based approaches with case studies. Case studies add a further dimension to theory based approaches as they provide rich information, through a narrative, about the elements which are evaluated (Joly et al., 2016). To date several different complementary approaches to ACIAR's continuing economic impact assessments have been trialled. Importantly these broader assessment frameworks need to be fit-for-purpose and flexible, reflecting the diversity of ACIAR's research across geographies, industries or sectors, and communities at various scales. The methods employed must be cost-effective given the level of investment and the likely learnings that can be drawn from an ex post assessment for future planning of research.

ACIAR EXAMPLES OF MIXED METHOD APPROACHES TO EX POST IMPACT ASSESSMENT

There are now a number of examples of ACIAR's application of theory based approaches and case studies applied to impact assessment. Initially these have included impact pathway analysis of oil palm research in Papua New Guinea (Fisher et al. 2012) and rodent control in rice crops (Palis, et al. 2013) to approaches that assist in determining social impacts such as women's empowerment, as well as intermediate and final impacts on capacity building, partnerships, networks and policy critical for the AR4D context as discussed above in the case of SNA. Two of these are briefly presented here to demonstrate the adaptation of methods that can complement the economic evaluation of impacts.

WOMEN'S EMPOWERMENT

An objective of ACIAR strategy is the empowerment of women and girls in academic and rural settings. ACIAR Gender Equity and Policy Strategy (2017) defines that: "Women's empowerment is a political and transformative process that analyses and challenges not only patriarchy, but also the mediating structures of class, race, ethnicity and economic structures that determined the nature of women's position and conditions." Based on this definition, ACIAR's Impact Assessments are increasingly incorporating methods, where applicable, to better identify and evaluate the social and economic impacts of its research on women and girls. It is important to note that it is critical to follow best practices for the collection of gender responsive data (e.g., Elias et al. 2013) to respect social, cultural local norms, maintain objectivity and avoid bias.

A recent impact assessment of a set of aquaculture projects undertaken by ACIAR in the Pacific (Clarke and Mikhailovich 2018) analysed the benefits and impacts for women involved in spat collection, mabé production and pearl handicraft. It applied a method adapted from the frameworks and assessment questions established by the International Centre for Research on Women (Golla et al 2011) and IFPRI's Women's Empowerment in Agriculture Index (WEAI). The assessors concluded that the Project's outcomes were contributing towards women's empowerment in four domains: capacity development - skills and knowledge, access and control of productive assets and income, workload and time and decision-making and leadership. The assessors concluded that a comprehensive gender and social impact assement requires disaggregated data from baseline, and such baseline were not always available in the projects they evaluated. ACIAR has now addressed this issue in its gender policy and developed project guidelines to ensure that research projects consider and incorporate gendered social relations in its design and implementation.

CAPACITY BUILDING

Capacity building is a core objective of ACIAR investments aimed at building scientific and policy capability amongst our country partners. In summary this capacity development includes strengthening institutions and organisations, informal individual on-the-job training, mentoring, learning by doing, and formal individual qualifications from Australian and partner country institutions. A causal pathway is inferred in that enabled individuals will go on to influence in the institutions which they work or interact with, and so contribute to institutional capacity building.

Capacity building has variously been assessed within the IAS including Gordon and Chadwick (2007) in which an evaluation framework was designed and applied to several research projects, attributing total welfare gains gained from the capacity built for each case study. Unsurprisingly the approach required substantial assumptions.

Partner agencies such as the International Development Research Centre (IDRC) has a focus on capacity interventions at the individual, organizational levels and in a network context. This has led to the development of a framework to capture capacity changes (Neilson and Lusthaus 2007). Capturing details of the capacity built by ACIAR research investments is an important first step in assessing impacts however valuing them within a traditional economic framework at project or program level remains a challenge.

Subsequent analyses for ACIAR by Gray et al. (2017) and Mullen et al. (2017) highlighted that the complementarity (or jointness in economic terms) of human capital with investment in research, technology, physical capital and infrastructure makes attributing benefits (and costs) to capacity building in isolation difficult limiting the application of an economic surplus approach. Further, the generation of externalities, where capacity built within one research project spills over into subsequent projects, institutions and even beyond agriculture are important (Mullen et al. 2017). Mullen et al. 2017 went on to apply a framework to assist in undertaking a more objective assessment of capacity building, eliciting capacity built by individuals and identifying how it has been utilized within the research project and trace any subsequent application and contribution to later projects and their outcomes.

CONCLUSIONS

ACIAR ex post impact assessments remain important to demonstrate the effectiveness of our investments in research for development and identify lessons to improve research planning and design. As the AR4D context evolves there is a broader recognition of the role of this research to contribute to systemic impacts in communities and societies. Contributors to AR4D such as ACIAR and our partners, in addition to rigorous economic assessments require a richer assessment of social, environmental, and intermediate impacts such as policy influence and capacity building.

Tools and methods to conduct more holistic approaches to impact assessments of research for development continue to be adapted and tested. Current literature on impact assessment in development frequently suggests theory based approaches and case studies within mixed methods frameworks. They hold potential for complementing economic analyses drawing upon various social science disciplines to add some rigour to assessing social, and capacity building impacts for example. ACIAR will continue to investigate innovative approaches to increase the accuracy and relevance of its impact assessments. It will as well, convene specialist workshops and continue to collaborate with impact assessment specialist in other organisations to refine and improve its methods. ACIAR projects will continue to improve the definition of clear impact pathways in their research proposals, such impact pathways will need to consider the potential economic, social and environmental impact of the research and collect data from baseline and during implementation along these pathways.

ACIAR's impact assessment efforts continue to adapt to increasing demands to better understand and describe contributions to not only economic impacts for households and communities but also elements of social, environmental, policy and capacity building outcomes that cannot be appropriately captured and described in economic terms alone. To date ACIAR has undertaken a number of impact assessments that apply theory based approaches and draw from various disciplines to examine elements such as women's empowerment, capacity building and networks and knowledge sharing, important final or intermediate impacts from its investments. This will remain an ongoing focus for ACIAR to better account for its contributions to development impacts in our partner countries and help draw lessons to improve on the effectiveness of future investments.

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INTERPRETING SOIL TEST RESULTS: What do all the Numbers Mean?

EDITED BY: Pam Hazelton & Brian Murphy
Third Edition
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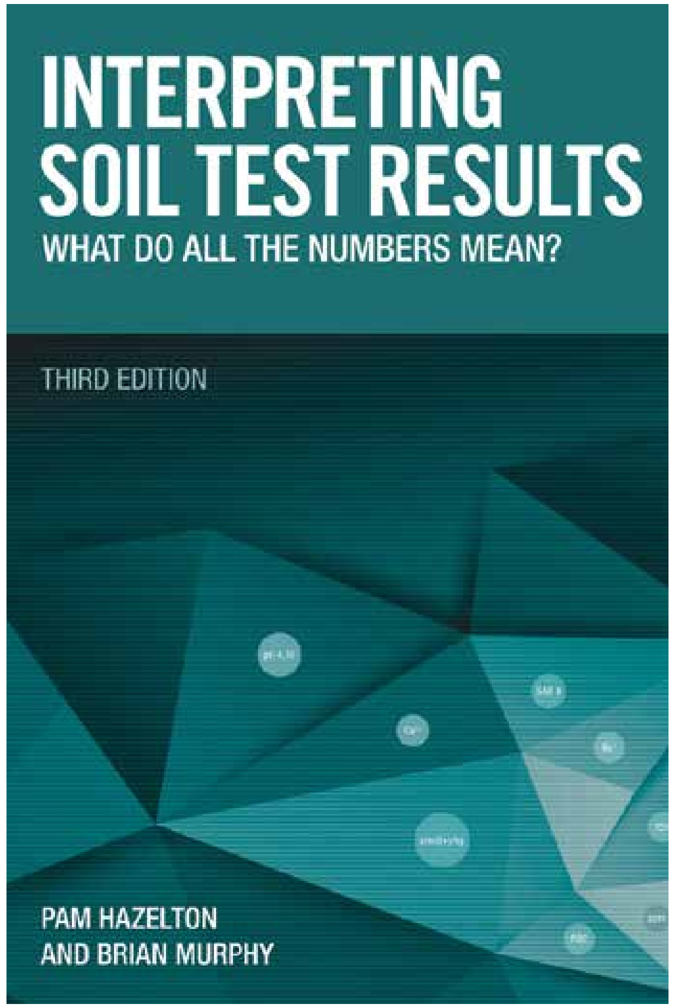
REVIEWED BY: Donald S. Loch
Honorary Senior Fellow, The University of Queensland



When Pam Hazelton and Brian Murphy wrote the First Edition in 1992, an 80-page loose leaf ring binder publication entitled What do all the numbers mean? A guide for the interpretation of soil test results, who would have thought that 24 years and two expanded editions later that it would have grown into such an iconic and widely used book across Australia? Clearly, this book has found a niche and met a need (or to be more accurate given its broad scope, a wide range of needs).

The First Edition was written specifically for officers in the then Soil Conservation Service of NSW to assist them in interpreting soil analysis data to advise on soil management issues because there was no alternative text available for this purpose. The Second Edition (2007) was revised and extended to a 168-page book covering a wider range of information from agriculture through to engineering. Encouraged by its widespread acceptance and use across a diverse audience of professionals and practitioners managing soils in Australia, the authors have further revised the Third Edition (2016) and increased it to a 200-page book.

The Third Edition is divided into individual chapters according to subject area, eight of which are recognisable from chapters in the previous edition, albeit with minor name changes: sampling, physical properties, engineering properties, erodibility and erosion hazard, chemical properties, wastewater and waste materials, soil contamination, and units and conversions. Except for the last mentioned, each of these has been revised and expanded by up to 7 pages, with a ninth chapter on soil organic matter added in its own right from the chapter on chemical properties in the previous edition.

Each chapter is further subdivided into major and minor sections. For example, Chapter 5 (Soil Chemical Properties) is divided into 14 major sections covering soil acidity, cation exchange capacity, individual macronutrients, micronutrients, plant tissue analysis, fertilisers, fertility ratings, nutrient removal in harvested product, salinity, sodicity, and acid sulfate soils. The trick to packing such a wealth and breadth of knowledge into what is (in essence) a small book, is to cover the basics on each topic and then to nominate further reading for those wanting more depth and detail on that subject.

The methodology used in most aspects of soils is regional rather than global in its application, hence the primary audience for the "Numbers Book" in terms of its specific detail is clearly Australian soil managers. Nevertheless, in the absence of any comparable text, readers in other countries could still benefit from the principles behind the detail. For example, many of the revisions in, and additions to, the Third Edition are directed towards environmental aspects of soil management, which are of increasing concern throughout the world.

In the event of a Fourth Edition (and I for one look forward to this), what could be added or changed? From my perspective, widening the range of examples (currently weighted strongly towards NSW and Victoria) to include more from northern and western Australia would help reinforce the national focus of this book. Sound sampling is fundamental to any measurement that we make in relation to soils, but this is perhaps now overshadowed somewhat in Chapter 1 by six pages of additions directed mainly at soil mapping, a more specialist area. At one level, it would have been nice to see, for example, the Albrecht system, the Reams Test and some of the many other darlings of the snake oil brigade debunked; but, in reality, it is one of the strengths of the book that it ignores such pseudoscience and deals only in straight, scientifically-based soil analysis.

But these are mere quibbles about a sound scientific text that will continue to be the "go to" book for its wide and increasing audience of professionals and practitioners. It is a power-packed, value-for-money small book that I would commend to anyone involved in soil management, particularly in Australia.

2018 ALAN RIXON MEMORIAL MEDAL

Kyra O'Sullivan being presented with the Alan Rixon Memorial Medal by Queensland Division committee member David Lloyd OAM FAIAST

In a ceremony at the University of Southern Queensland (USQ) on 5 April 2019, the Queensland Division of the Ag Institute Australia (AIA) proudly presented Environmental Engineering graduate Ms Kyra O'Sullivan with the Alan Rixon Memorial Medal. This award, including a mounted AIA medal, a $500 cash prize and one year's membership of AIA commemorates Dr Alan Rixon, a long serving foundation member of the Faculty who was renowned for his pastoral care and who became Head of Agricultural Engineering. Kyra demonstrated outstanding performance in the Environmental major in her Bachelor of Engineering degree.

Kyra's interest in Environmental Engineering stemmed from her life on a beef cattle and peanut cropping farm near Kingaroy in the South Burnett Region of southern Queensland, where she developed a keen interest in agriculture and the environment. She became particularly interested in food security and the challenges of how, as a society, we will continue to feed the world as climate change takes its effect.

Thus, she applied to USQ to study Environmental Engineering where she was offered a scholarship to begin study in 2015. She enjoyed the study conditions presented, the close interaction with the staff and the many opportunities provided that included:

- At the conclusion of 1st year, completing research for the Cotton Research and Development Corporation and the Centre for Agricultural Engineering on the subject 'How wet and dry cycles affect mineral nitrogen supply from conventional and enhanced efficiency fertilisers'.
- Receiving an overseas scholarship to study an Environmental Engineering course in Germany during her 2nd year holidays which focused on renewable energy technologies in Europe, land use efficiency and innovations in ecofriendly building design. This enabled networking with Engineering students and lecturers from around the world.
- Completing work experience at New Hope Group's Acland Mine, which included work in mine rehabilitation to restore land for grazing and cropping purposes.
- Competing in the Australian Soil Judging Competition as part of her coursework.

Kyra O'Sullivan was also active in University affairs. She was appointed a USQ Student Ambassador throughout her course, travelling around Queensland and northern New South Wales to promote USQ tertiary education, particularly engineering, to high school students. She worked as a resident advisor at USQ Residential Colleges, managing Steele Rudd College in her third and fourth years of university, and thus developing her own time and people management skills. As a tribute to her involvement, dexterity and high regard, she graduated as USQ's Class of 2018 Valedictorian.

Since graduation, she has been appointed to a position at GHD, an engineering consultancy in Brisbane in the Land Contamination Assessment and Remediation Team. This is likely to present the opportunity to travel Australia and, eventually, travel and work overseas.

The AIA acknowledges that financial assistance for Kyra O'Sullivan's project was provided by Associate Professor Bernadette McCabe's Advance Queensland Fellowship with support from the University of Southern Queensland's Centre for Agricultural Engineering.

As a component of her assessment for the Rixon Medal, Kyra O'Sullivan's research study, "Soil physical and chemical properties as affected by long-term land application of paunch", was a project conducted in association with the Oakey Beef Exports Pty Ltd abattoir and supervised by Assoc. Prof. Bernadette McCabe and Dr Diogenes Antille. Her work is summarised as follows:

One by-product of the red meat processing industry is paunch, the stomach contents of the animal after slaughter. Globally, 15 million tonnes of paunch are produced each year by the red meat processing industry. Many abattoirs are investigating methods of recycling and utilising paunch waste as a useful and profitable material, particularly as a soil conditioner or bagged compost for use in domestic gardens. Paunch contains a high level of organic matter and other nutrients essential for plant growth. Some abattoirs apply composted paunch directly to broad acre agricultural land, but little is understood about optimal application rates, composting periods or the quantifiable benefits of applying paunch to the soil.

This project investigated some of the current deficiencies in knowledge associated with the application of paunch to agricultural soils - changes in key soil physical and chemical indicators (soil bulk density and soil strength, aggregate stability, soil hardness, saturated hydraulic conductivity, salinity (EC), soil organic matter, pH and texture) at sites that had used paunch as a soil amendment for short (<5 years) and long (>20 years) periods of time.

Soil samples were tested in 20cm increments from the surface to 80cm down the profile.

Comparisons were made on four dark self mulching clay soil sites that were managed and owned by Oakey Beef Exports Pty. Ltd. Sites 1 (irrigated) and 2 (non-irrigated) had paunch applied for < 5 years while site 3 (long-term) had paunch applied for >20 years. Site 4 (control) was a nearby site which had no paunch applied. In addition, site 3 had been treated with abattoir wastewater sporadically over a number of years.

It was found that the short-term application (< 5 years) of paunch did not improve the soil physical, chemical or hydraulic properties assessed in this study. Significant soil compaction caused by traffic and tillage associated with both standard field cropping operations was exacerbated by vehicle traffic associated with the application of paunch. Compaction significantly affected soil physical and hydraulic properties by decreasing water infiltration rates and increasing soil strength, thus adversely affecting soil processes and function.

However, the application of paunch in the long term (>20 years) improved soil physical characteristics and hydraulic properties suggesting that >5 years of paunch application were needed before a significant improvement of soil properties was able to be measured. After that time, the soil had a greater resistance to compaction, had higher infiltration rate, relatively lower penetration resistance and lower soil bulk density than at the short-term sites. Aggregate stability in the topsoil (0-20 cm) of the long term application site was better than at any other site and soil organic matter was increased. However there was no measurable effect below that depth. Improved soil physical and hydraulic properties at this site are explained by increased levels of soil organic matter in the topsoil.

This study concluded that the long-term application of paunch improves soil quality (as determined by the range of soil properties assessed in this study) due most probably to the increase of soil organic matter in the surface 20cm of the profile. However, no positive effects and some negative (an increase in soil compaction, probably associated with traffic movement while applying paunch) were measured where paunch was applied for five or fewer years.

Further research is needed to determine if the benefits provided by the long-term application of paunch could be accelerated and further enhanced by improving industry practices such as the implementation of controlled traffic farming, tandem operations (e.g. paunch application and incorporation in a single pass), subsoil manuring and by restricting spreading to dry surface soil conditions.

Additionally, further research could include the construction of an application rate and timing framework for farmers to maximise the benefits of paunch application and for an extension of further studies to different climatic localities and soil types in proximity to locations where paunch is commercially available.

Barry James White

21 Sept 1942 - 26 Dec 2018

Authors: Ian Robinson & Greg McKeon

In December 2018, Queensland and Australia lost one of their most talented agricultural professionals.

Barry White grew up in Mt Tyson on the Darling Downs and was educated at Downlands in Toowoomba.

At the tender age of 17 his professional life suffered a temporary setback when he lost interest in his second year engineering studies at the University of Queensland. This was primarily due to his difficulties in technical drawing resulting from being forced to change from left to right handed at a young age. He had also discovered statistics and probabilities which lead to a strong interest in economics as a profession.

He quickly found a job as a Cadet in the soil conservation service of the Queensland Dept. of Agriculture and Stock. He was essentially a "hole digger" in a team investigating the relationship between soil erosion, soil moisture and crop productivity on the Darling Downs.

Barry completed an Economics degree at UQ as an external student in 1964. On graduating he was appointed to the Development Planning Branch of the Department in Brisbane. At this early stage of his career his skills in quantitative analysis came into play. This Branch had been established to cordinate major developments in the State's agriculture. These included the brigalow development scheme and several large irrigation schemes. Barry played a significant role in the economic assessment of these projects including the Burdekin Dam. He had high level social skills and was valued for his ability to work in teams of diverse professionals and to play a lead role.

During this period Barry also participated in a cloud seeding trial conducted by CSIRO in several regions of Eastern Australia including the Darling Downs. His contribution impressed Dr Taffy Bowen who became a mentor to Barry as he developed his capacity as an agroclimatologist.

To add to his skill set Barry completed a Phd, A Simulation Based Evaluation of Queensland's Northern Sheep Industry, at James Cook university in 1978. This research integrated and modelled the soil/plant/animal/financial systems for a typical wool growing enterprise in the mitchell grass country of northern Queensland. Modelling and simulation of agricultural enterprises were in their infancy at this time. By comparing model results with observed data Barry was able to analyse a range of management and policy issues.

This thesis was an outstanding piece of research widely regarded as being well ahead of its time.

During the 1980's Barry began to focus on an issue which would define the rest of his career. In a country in which climate variability represents the greatest challenge facing primary producers he saw the provision of improved and more precise climate information as critical for both economic performance and resource management.

His diverse skill set was recognised within the State Department and over a ten year period he was appointed Director of four separate professional branches - Biometry, Economic Services, Marketing Services and Consultancies and Market Development. In the latter he played a pivotal role in preparing the ground for the Lao/Queensland Agricultural Cooperation Agreement.

He had high level social skills and was valued for his ability to work in teams of diverse professionals and to play a lead role.

Given these achievements in leading his colleagues it was to be expected that Barry would aspire to appointment at the highest levels of the Department.

This was not to be. In 1994 he decided to pursue a career as a consultant at the national level. He had prepared the ground well for this career change. Several years before he had been appointed first to the Barley Research Council, then to the Wheat Research Council and finally to the Grains Research and Development Corporation.

A major Australia wide project undertaken by Barry for GRDC was the development and implementation of a system for the evaluation of research projects funded by the Corporation. Another early project was a review of Australian applications for seasonal climate forecasting for the Asia Pacific Network for Climate Change. Barry presented the results of this review to the Tokyo Scientific Advisory Committee.

These appointments to the Research Councils provided Barry with a powerful network of contacts so important in establishing his national consultancy. Federal funding of the R and D corporations especially the Land and Water Resources Research and Development Corporation(LWRRDC) was also critical to his success. Work flowed freely when he was appointed as their Coordinator (Climate Variability).

One of the many projects in which Barry played a lead role was the development of the SILO database combining the Bureau of Meterology's datasets with the delivery capability of the Drought Group in QDPI. Another major project for which Barry arranged funding was the development of the AussieGRASS model which simulated the impact of climate variability on pasture growth.

In most of the work that he did at this stage of his career Barry recognised the need to harness the synergy of diverse professional groups located in a wide range of organisations. Two projects in particular, Drought Plan and Oceans to Farms, are prime examples of the success of this modus operandi.

This was a hugely successful period of his professional life and it is understood that for much of this lengthly period he was fully booked years in advance. An indication of his professional reputation as an agroclimatologist can be gained from his plenary paper in 2000 in an international publication Applications of Seasonal Climate Forecasting in Agriculture and Natural Ecosystems - the Australian Experience. In 2004 he was invited by the United States Academy of Sciences to participate in a workshop on seasonal climate forecasting.

The enduring focus of much of his work with LWRRDC in which he showed national leadership was the highly variable climatic environment in which Australian agriculture operates. He relentlessly pursued the need to provide primary producers with more sophisticated climate indicators to enhance their ability to deal with this variability.

In focussing on this issue Barry cited a seminal paper by H.M.Treloar published in the Journal of the Insitute of Agricultural Science as early as 1952. This paper was followed by several CSIRO papers in the 1960's one of which, by Troup, identified the Southern Oscilation Index (SOI). Decades later the Bureau of Meterology built on this early work and incorporated El Nino Southern Oscillation (ENSO) cycles in information disseminated.

In attempting to come to an overall appreciation of Barry White's professional life, particularly the latter decades, it is fair to say that he was the leading agroclimatologist of his era. He was instrumental in redefining the quality of climate information provided to the rural sector and to the many other users of such data. The continuing economic and environmental gains from the uptake of this information would be large indeed.

Turning to comments of a more personal nature, mention must be made of Barry's love of rugby. As a young man in Toowoomba he, together with brothers Kerry and Geoff, established the Rangers rugby union club in 1963. He went on to play first class rugby for Brothers club in Brisbane and scored two tries in an epic grand final win against University. He played for Queensland on several occasions and was regarded as an outstanding lineout jumper. In later life he had the immense satisfaction of being at Cardiff in 1999 to see the Wallabies beat France in the World Cup final.

Friends and colleagues alike found Barry to be engaging, entertaining and challenging. He had a keen sense of social justice and was formidable when arguing his case, always evidence based, on any number of issues. The application of his acute intellect and his warm and generous friendship will be keenly missed.

Barry is survived by his wife Robyn and sons Andrew and Peter.

Dr Nigel Monteith passed away on 21 August 2019 at the age of 91.

Nigel graduated BSc Agr from Sydney University in 1950 and holds an MS and PhD in Soil Science. From 1955 to 1975, he worked for CSR in Fiji and for FAO on agricultural development projects in Argentina, Mexico and Iran.

In 1975 he joined the World Bank as an agriculture specialist in the Europe Middle East and North African Division based in Washington DC. He returned to Australia in 1980 to take up the position of Managing Director of AACM (Australian Agricultural Consulting & Management Company) in Adelaide. AACM carried out agricultural development projects in some 25 countries under contract to aid organisations. He retired from AACM in 1993 and subsequently chaired the Meat & Livestock Research & Development Corporation, the South Australian Native Vegetation Council and the Federal Government's Council for Sustainable Vegetation Management and was also a Board Member of SAGRIC International. He finally retired in 2002.

Nigel is survived by his wife, Nancy, and daughters, Deborah, Vicki, Julie and Amanda, 6 grandchildren and 3 great-grandchildren.

LETTER TO THE EDITOR

THE AIA'S CLIMATE CHANGE AND ENERGY POLICIES

I would like to associate myself with the letter from Peter Finlayson in the recent 2018 issue of the journal *(Vol.29 No.2/Vol.30 No.1, p. 73)*. It is not appropriate for the AIA to enunciate a policy that is not only contestable, but which has not been discussed or endorsed by members.

In addition to Howard Brady mentioned by Finlayson, there are many other eminent *"climate scientists"* who are using the rigours of science to question the methodologies, data and conclusions of IPCC scientists about the primacy of anthropogenic causes of global warming. One only has to read some of the *"climatically incorrect"* literature, such as the books of Ian Plimer, Patrick Michaels, Roy Spencer, and Bob Carter *et al*., to conclude that the scientific jury is still out on the determinants of climate change, especially over the longer term. As I see it at present, the trends in climate seem to be determined primarily by nature rather than extant human activities. At best the latter seem to affect movements around the inexorable trends rather than the trends themselves.

If indeed we introduced policies like emissions reduction targets, an unpopular carbon tax and costly renewable energy targets because of the precautionary principle and prudent risk management, to validate them the focus still should be on the science, not on alternate policies. The role of the AIA should be to focus on the science and not become an advocacy group for particular policies. The need is to objectively inform the public about the continuing scientific debates and defer the moves towards more second- and third-best policies to address what may be a non-problem.

Climate change is real and always has been. What is still in dispute are its determinants and the degrees of freedom that we have to mitigate it and the value, cost and desirability of doing so, compared with marshalling resources to be better able to adapt to whatever nature serves up to us.

Jim Ryan FAIAST, DLMAARES
24 October 2018

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