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Abstract:
Agricultural innovation systems (AIS) are increasingly recognized as complex adaptive systems in which interventions cannot be expected to create predictable, linear impacts. Nevertheless, the logic models and theory of change (ToC) used by standard-setting international agricultural research agencies and donors assume that agricultural research will create impact through a predictable linear adoption pathway which largely ignores the complexity dynamics of AIS, and which misses important alternate pathways through which agricultural research can improve system performance and generate sustainable development impact. Despite a growing body of literature calling for more dynamic, flexible and "complexity-aware" approaches to monitoring and evaluation, few concrete examples exist of ToC that takes complexity dynamics within AIS into account, or provide guidance on how such theories could be developed. This paper addresses this gap by presenting an example of how an empirically-grounded, complexity-aware ToC can be developed and what such a model might look like in the context of a particular type of program intervention. Two detailed case studies are presented from an agricultural research program which was explicitly seeking to work in a "complexity-aware" way within aquatic agricultural systems in Zambia and the Philippines. Through an analysis of the outcomes of these interventions, the pathways through which they began to produce impacts, and the causal factors at play, we derive a "complexity-aware" ToC to model how the cases worked. This middle-range model, as well as an overarching model that we derive from it, offer an alternate narrative of how development change can be produced in agricultural systems, one which aligns with insights from complexity science and which, we argue, more closely represents the ways in which many research for development interventions work in practice. The nested ToC offers a starting point for asking a different set of evaluation and research questions which may be

more relevant to participatory research efforts working from within a complexity-aware, agricultural innovation systems perspective.

Introduction

Agricultural innovation systems are increasingly understood to be complex adaptive systems, a type of complex system with specific characteristics that hold significant implications for interventions seeking to create "impact" within these systems. In complex adaptive systems (CAS), a wide array of heterogeneous actors adapt their strategies and actions based on the actions of others and on changing system conditions, while contributing to these changing conditions through their evolving responses to them (Spielman et al., 2009; Klerkx et., al. 2010). As a result of the dynamic nature of these inter-connected changes, CAS produce unpredictable yet recognizable patterns, such as co-evolution, path dependency and emergent properties, which cannot be predicted by understanding the behavior of discreet actors within the system (Axelrod and Cohen, 1999; Miller and Page, 2007). In CAS, small initial changes in system conditions can create large and unanticipated impacts throughout the system, even when system components are connected in ways that are causally deterministic (Miller and Page, 2007).

While complex adaptive systems do not readily lend themselves to control or management due to their unpredictable nature (Spielman, 2009; Arkesteijn et. al. 2015), they can be successfully intervened into if the intervener has an understanding of the dynamics of CAS and how to harness these (Williams, 2010). Snowden (2010) proposes a strategy of seeing program intervention as catalytic probes that stimulate patterns of activity. Program staff then stabilize and amplify beneficial patterns and dampen down and kill off negative ones. This is similar to the improvisational model of change management proposed by Orlikowski and Hoffman (1997) in which planned change gives rise to emergent change that then provides opportunity for further planned change.

A sub-set of agricultural research interventions over the past twenty years have been designed by actors who are aware of the complex nature of agricultural innovation systems (AIS). These interventions have sought to harness the dynamics of complexity to catalyze system learning, innovation, and adaptive change within AIS. Examples of these "complexity-aware" approaches to agricultural research include Integrated Natural Resource Management in the 1990s (Campbell and Sayer, 2003), Learning and Action Research in the 2000s (Probst and Hagmann, 2003), and Adaptive Collaborative Approaches (Ojha et al., 2012). Such approaches cast extension agents and researchers in the role of "innovation brokers" (Klerkx et al., 2012), and facilitators of multi-stakeholder innovation processes (Dugan, et. al. 2013; van Paassen, et. al. 2014; Apgar, et. al. 2015; Kraaijvanger, et. al 2016). Klerkx et al. (2012) provides a summary of the evolution of systems and complexity-aware approaches based on a literature review. Table 1, adapted from that paper, compares the traditional linear approach to technology development and transfer with a complexity-aware one to illustrate the dimensions of difference between the two approaches.

Table 1: Comparison of the traditional approach to agricultural research for development with a recent complexity-aware one (adapted from Klerkx et al. (2012) and Douthwaite, 2016)

Characteristics	Linear approach to AR4D	Complexity-aware approach to AR4D
Name	"Transfer of technology" or "pipeline"	"Agricultural innovation systems"
Era	Central since 1960s to present	From 2000s to present
Mental model and activities	Supply technology to next user	Co-develop innovation involving multi-actor processes and partnerships
Knowledge and disciplines	Single discipline driven (mainly plant breeding)	Transdisciplinary, holistic systems perspective
Drivers	Supply-push from research	Responsiveness to changing contexts, patterns of interaction
Source of innovation	Scientists	Multiple actors, innovation platforms
Role of farmers	Adopters or laggards	Partners, entrepreneurs, innovators exerting demands
Role of scientists	Innovators	Partners, one of many responding to demands
Key changes sought	Benefits accruing from technology adoption	Institutional change, increase in system capacity to innovate
Dynamic	Research begins quickly according to a pre-defined agenda	Intervention begins by building relationships and trust through an open research agenda

While much has been written on the need for systems approaches when intervening into complex natural, social, and/or economic systems, less has been said about the outcomes that result from using these approaches. There is, however, a small body of empirical work which is starting to show that these approaches generate benefits that contribute to the ability of local systems to evolve in ways that contribute to inclusive and sustainable development. Complexity-aware research interventions into AIS can build multiple types of social capital (Uphoff and Wijayara, 2000), increase system actors' skills and confidence in systematic experimentation, and lead to the development of new practices and technologies as well as the application of existing agricultural knowledge and technology to new local contexts (Ayele et. al. 2012; Sterk 2013; Hounkonnou et. al. 2016; Kraaijvanger et al., 2016). There is also evidence that these approaches improve the functioning of local and regional institutions (Hounkonnou et. al., 2016) as well as the linkages and relationships between key system actors (Douthwaite et. al., 2015). The benefits of these outcomes can be significant for rural smallholders and other system stakeholders: Uphoff and Wijayara (2000) found that investment in farmer-led irrigation groups built specific forms of cognitive and structural social capital that allowed farmers to significantly increased agricultural productivity in the face of sudden and severe water scarcity over thousands of hectares in the Gal Oya area of Sri Lanka.

Despite evidence that complexity-aware approaches can produce valuable results, the dominant narrative about how agricultural research creates impact, particularly in the context of developing economies, remains complexity-blind (Ekboir, 2003; Klerkx et. al. 2012; Schut et al., 2015). This narrative holds that agricultural researchers develop knowledge, technology, and processes to address the problems of farmers and other agricultural system actors. These innovations are passed on to other organizations who are tasked with promoting their adoption and use (Hellin et. al. 2006). Impact for end-users and for the system derives from the adoption, use, and scaling of these improved technologies and ways of doing things, which can include new or improved methods (Ayele et. al. 2012; Schut et. al. 2015; Gaunand et. al. 2015; Joly et. al. 2015; Wigboldus et. al. 2016). This model has several names in agriculture including the "pipeline" approach to innovation (Sumberg, 2005), the "central source of innovation" model (Biggs, 1990) and the "transfer of technology" or "diffusion of innovation" approach (Klerkx et. al. 2012). In industry, the model is called the "delivery" mode or "over-the-wall" approach (Leonard-Barton, 1998). We call this conventional model the "adoption impact pathway" where "impact pathway" refers to a causal chain of inputs, processes and outcomes that lead to impact.[1]

In the past five years, several studies have sought to better understand and describe how agricultural research efforts create societal impact, focusing on uncovering diverse impact pathways and on understanding aspects of the research process which themselves contribute to producing and sustaining impact over time (Gaunand, et. al. 2015; Schut, et. al. 2014). These studies have highlighted the importance of process-related factors, such as the quality and duration of research partnerships, the nature of roles and relationships between researchers and stakeholders, and the type of research strategies used in particular contexts as important determinants of impact (Joly, et. al. 2015; Schut, et. al. 2014). However, the insights and findings emerging from this work have not yet been incorporated into usable, alternative theories of change (ToC) which could guide the program planning and evaluation work of major actors in international agricultural research.

Despite significant criticism from within the literature, the long-established adoption impact pathway therefore remains the dominant overarching change narrative for major international funders of research and innovation related to global development (Dalrymple 2008; Renkow & Byerlee, 2010). It is also the dominant change narrative for agenda-setting institutions for international agricultural research such as the Food and Agriculture Organization (FAO) and the CGIAR[2] (formerly known as the Consultative Group on International Agricultural Research). The adoption impact pathway has the advantage of being familiar, simple, and offering a plausible path to touching the lives of large numbers of people. The extent and benefits of adoption and resulting returns on investment can be

[1] An impact pathway is a more descriptive synonym for "theory of change" (ToCo) (Douthwaite et al., 2003), which describes how and why a program works (Weiss, 1995). ToC is useful to guide implementation and as the basis of theory-driven evaluations (Douthwaite et al., 2003; Stame, 2004).

[2] The CGIAR is a worldwide partnership addressing agricultural research for development carried out by 15 research centers. The CGIAR's vision is a world free of poverty, hunger and environmental degradation (CGIAR, 2016). As of 2014, the CGIAR employed more than 8,500 researchers and support staff worldwide, with an annual budget of US $800 million (Agropolis International, 2015). While CGIAR funds represent a small proportion of the total global funds invested in agricultural research in developing countries, the CGIAR influences how this investment is conceptualized, implemented and evaluated.

calculated and claims can be made for the impacts of specific technologies and practices that have achieved wide-scale use, such as cell phones, mobile money, or improved seed varieties.

While this impact pathway applies to research carried out within existing innovation trajectories (Ekboir, 2003), for example plant breeding and maintaining the yield potential of modern crop varieties, the overwhelming focus on it has obscured other ways in which agricultural research and innovation efforts are producing development impact. Complexity-aware programs are particularly disadvantaged by the adoption impact pathway narrative because they are not attempting to manage towards predicable outcomes within existing innovation trajectories, but rather to provoke and then harness beneficial system interactions and dynamics (Douthwaite et al. 2003; Arkesteijn et al. 2015; Ton et al. 2014) in the process of catalyzing and supporting new ones. These programs therefore cannot easily forecast their impacts ex ante and may also produce unexpected impacts which are not included in the adoption impact pathway and which can therefore remain invisible to evaluators, donors, and organizational decision-makers. Complexity-aware programs, therefore, face challenges in communicating their impact to donors, particularly in the absence of causal models that more accurately describe how these programs work and what results they produce.

In this paper, we focus on the case of one program which found itself facing the challenge of communicating its way of working and research outcomes: the CGIAR Research Program on Aquatic Agricultural Systems (AAS), for which the first author worked as a research theme leader for four years. As we will illustrate, AAS was operating in a complexity-aware way, yet four years into its intended 12-year lifespan, the program was closed by the CGIAR because the impacts it was producing were not judged to be significant in terms of their ability to contribute to the CGIAR's overarching results framework, based on the adoption impact pathway (CGIAR Consortium, 2015). Important outcomes emerging from the program, such as the program's contribution to building capacity to innovate in the geographic areas in which it worked, were not seen or valued for their ability to contribute to the CGIAR's overall impact goal to bring 30 million people out of poverty by 2024 (CGIAR, 2016).

The story of this program and its closure highlights a gap in the existing literature and in practice which this paper addresses: the lack of concrete, empirically-based theories of change that are consistent with a complexity perspective and that demonstrate how programs engaging with complexity produce development outcomes and impacts. There is a growing literature calling for complexity-aware evaluation of programs that intervene in complex systems (e.g. Douthwaite et al., 2003; Stame, 2004; Rogers, 2008; van Mierlo et al., 2010; Patton, 2011; Britt and Patsalides, 2013; Arkesteijn et. al. 2015), but these authors stop short of developing ToC that could be used or tested in these evaluation processes. Similarly, a number of authors within the agricultural systems and evaluation literature have argued for and proposed frameworks to inform the implementation and evaluation of complexity-aware interventions (e.g., Pretty and Chambers, Ekboir, 2003; Hall et al., 2003; Kristjanson et al., 2009; Nederlof et al. 2007), but these frameworks have remained largely normative and have not been translated into empirically-grounded models with clear implications for practice. We have found one paper to date (Douthwaite et al., 2003) that has proposed a theory of change (ToC) to guide implementation and evaluation of projects that develop embodied technologies in complex systems. However, this ToC does not model how the agricultural research process builds the capacity of the people and institutions who take part, and how that capacity fosters innovation.

In this paper, we develop a non-linear ToC that models how research outputs as well as research processes led to outcomes in the case of a program for which research process and empowerment were seen as important pathways to impact from the outset. We conducted a detailed analysis of two cases of successful program implementation, examining how research process and output led to early outcomes and impacts and describing the causal dynamics at play as identified by key stakeholders and researchers (both internal and external) who were involved in each of the cases. Drawing from our understanding of complexity science, realist evaluation, and reflexive monitoring and evaluation, we develop a timeline and causal narrative for each intervention and construct from these a middle-range ToC which describes the key features and dynamics present in both cases. As a middle-range theory, this model seeks to describe the key dynamics of the cases at a level of abstraction which might allow the model to capture essential features of other complexity-aware interventions into agricultural innovation systems. We also develop an overarching ToC, under which the middle-range theory is nested, that identifies self-reinforcing feedback loops that are possible when programs pursue both technology development and empowerment pathways.

Theoretical Foundations

In order to develop an empirically-based, complexity-aware ToC, we draw on several different bodies of theory to develop the conceptual framework underlying our approach. Several core concepts informing our approach come from Realist Evaluation, starting with the idea that the degree to which programs bring about change depends on how people interpret and use what programs provide. Programs trigger underlying causal mechanisms, often rooted in the cognitive processes going on inside people's heads, which are influenced by context and history (Pawson and Tilley, 1999; Westhorp, 2014). According to Weiss (1997) mechanisms are the responses that program activities generate. In this paper, we develop what Pawson (2013) calls a middle-range theory that can abstract across cases to identify the common mechanisms at work. Middle-range theory is useful because it can guide new projects in developing their context-specific or particular ToC, and provide a framework for accumulating learning (Ibid, 2013). According to Pawson and Tilley (1997, p.123-4):

> The basic idea of middle-range theory is that the propositions do not have to be developed de novo on the basis of local wisdom in each investigation. Rather they are likely to have a common thread running through them traceable to [the] more abstract analytic frameworks …".

In developing an approach to creating a complexity-aware ToC, we also draw on the idea that useful ToC should be nested (Mayne, 2015) such that a program or research system will have an overarching ToC, describing its high-level causal assumptions, under which more detailed and grounded ToC is developed for individual projects, or elements of them. Nesting helps prevent ToC from becoming overly complicated such that the diagrams no longer readily communicate their causal logic.

We take as given that, even in complex systems, change happens through relatively stable patterns of activities that emerge and die away over time. These patterns have been called technology trajectories (Ekboir, 2003), innovation trajectories (Douthwaite and Gummert, 2011) outcome trajectories (Paz-Ybarnegaray and Douthwaite, 2016) and beneficial coherence within attractors (Snowden, 2010). An empirically-based ToC should give a sense of recurring patterns of behavior that programs may have catalyzed or contributed to catalyzing, along with other factors. Linked to this idea is Scriven's (1976) observation that successful programs have a distinctive *modus operandi*--at some level of abstraction, they trigger similar mechanisms across the places in which they work, even if those sites differ to some extent in context and history. The final element informing our conceptual framework is the finding from Senge's (1990) systems dynamics work that complex processes have self-reinforcing and dampening processes that interact with each other. Self-reinforcing processes provide for leverage, or in other words, for relatively small interventions to have a large impact. Complexity-aware ToC should model for both self-reinforcing and dampening processes.

Methodology

Overview

In this paper, we present two cases from the AAS research portfolio which program staff highlighted as cases that were starting to produce strong outcomes at the time the program was closed. Through in-depth case histories, we present the details of each case and then examine these to discern the dynamics and causal mechanisms operating in each case: what outcomes were emerging, what impact pathways these were leading to, and what key factors were combining to create these outcomes, from the perspectives of program staff, researchers, and evaluators engaged in a six-month-long process of documenting and assessing each case. We use these findings to inductively develop a middle-range ToC to describe the emerging outcome trajectory common to both cases. We also develop a higher-level model with broader applicability in which the first model is nested. We offer both models and their accompanying narratives as alternate ToC – alternative narratives for how agricultural research can create impact within rural agricultural innovation systems. The two models allow us to see different types of outcomes, a different impact pathway, and important causal connections and mechanisms which we are blind to when viewing complexity-aware programs through the lens of the conventional adoption impact pathway. We conclude by drawing out the implications of complexity-aware ToC for generating evaluation and research questions that are more useful and relevant to programs seeking to harness the dynamics of complexity within agricultural innovation systems.

Selecting the cases

The two cases presented in this paper were developed by AAS program staff to document key areas of program learning and results following a program review conducted in January 2015 (Douthwaite et al. 2015). The review brought together staff from each of AAS's five regional hubs to engage in cross-hub learning regarding emerging program outcomes. The review identified several cross-cutting themes, including community engagement, partnerships and "inclusive science". This refers to instances in which researchers and scientists found themselves working with farmers and local stakeholders in a way that was different from business as usual and which involved shifting from top down and transactional relationships towards engaged and more equal partnership. This term was agreed upon by participants in the workshop as one that captured their shared experience of using AAS' approach of "research in development" (described below) as compared with standard approaches to agricultural research for development (R4D).

Five inclusive science cases were identified by consensus in the January 2015 program review by hub teams of two to five people, including the hub leader. The choice was later verified with the full hub teams, respectively. From five inclusive science cases developed by AAS staff, four were selected for development and publication in a chapter in the program report *Research in development: Learning from the CGIAR Research Program on Aquatic and Agricultural Systems* (Douthwaite et al., 2015). Other chapters of the report covered other cross-cutting themes. Following publication of the report, we selected two of the four "inclusive science" cases as the source material for this paper, choosing those we independently assessed as best exemplifying the participatory research approach at the heart of AAS' Research in Development (RinD) methodology. In seeking to understand and model how participatory research interventions bring about change within complex agricultural innovation systems, we needed cases which exemplified a complexity-aware, participatory approach. These cases met that criteria and were therefore selected for further development and analysis for this paper.

Data sources and analysis

The original four cases included in the AAS program report were selected and developed using case study methodology (Yin, 1989) as described in more detail in the report (Douthwaite et al., 2015). Each case had two hub-level authors who developed a timeline of key events and processes in the case and a narrative to describe causal links between them. This timeline and narrative was developed from their own direct experience as participants in the work and from a range of source materials, including program monitoring and evaluation data, existing research and program reports, and staff reflection during after-action reviews. Drafts produced by hub-level authors were reviewed and interrogated by an international AAS research team member (a co-author on this paper), resulting in several rounds of clarification, additional data collection, and verification at the local level, until the case histories were deemed to be sufficiently documented, triangulated, and verified.

For this paper, we re-analyzed the two selected case histories to understand what outcomes were achieved and how, with a particular focus on understanding the dynamics of causality present in the cases. We cross-checked and supplemented the initial case material with data from a separate Outcome Evidencing process conducting by AAS staff between March 2014-2015, subsequently published as a methods note in the American Journal of Evaluation (Paz-Ybarnegaray and Douthwaite, 2016). Outcome Evidencing involved identifying, clustering, and verifying outcomes and impact pathways for each of the hubs, conducted with participation from hub-level staff, local stakeholders, international research staff from AAS, and independent evaluators. The Outcome Evidencing process resulted in hub-level outcome evidencing reports for both countries (Paz-Ybarnegaray, 2014; Chisonga et al., 2014). Revisiting the cases with new data, using a researcher external to the AAS program who was attentive to potential biases, helped strengthen the internal validity of the cases. We then used the cases to develop a middle-level ToC describing how RinD inputs and other factors contributed to observed outcomes. We also built on existing synthesis from the final chapter of the program report (Douthwaite et al. 2015).

Background on the cases

The CGIAR Research Program on Aquatic Agricultural Systems (AAS) was one of fifteen research programs implemented by the CGIAR, and was launched in 2011 with the aim of reducing poverty and improving food security for small-scale fishers and farmers dependent on agricultural systems (AAS 2011). AAS established operations in locations bounded by an important aquatic agricultural system, which the program referred to as "hubs." These were strategic "locations within key aquatic agricultural systems where innovation and learning can bring about development outcomes" (AAS 2013, p. 5). AAS hubs were set up in five locations: Zambia, Bangladesh, Cambodia, the Philippines and Solomon Islands.

AAS set out to achieve its goal by developing a complexity-aware research approach called "research in development" or RinD for short (Dugan et al. 2013). The program coined the term to signal its intention to carry out research in support of—and embedded within--on-going development processes, in contrast to research "for" development, in which researchers produce outputs from outside a system to be adopted by users within that. The RinD approach involved an engagement process in which the program facilitated stakeholders both at the hub-level (regional) and local community level to articulate their respective priorities and visions. Program staff then brokered agreement on specific issues that villagers and hub-level stakeholders were motivated to work on as a way of developing relevant technologies as well as building linkages and capacity for local development.

The RinD approach is based on and uses techniques from participatory action research (PAR). PAR is a participatory process of inquiry that uses iterations of acting and reflecting to answer questions about real life concerns to improve the wellbeing of those engaged (Reason and Bradbury, 2008; Apgar and Douthwaite, 2013). The process is dynamic and continuous, enabling feedback in real time, unlike most research endeavors that present findings after the fact. The participatory and action-oriented focus is assumed to build ownership of the process by the participants, who learn through their own experiences and are able to change their own lives and social worlds (Apgar and Douthwaite, 2013). Participants volunteer to engage based on interest and motivation, rather than on the basis of a standard menu or set of criteria. The RinD approach used by AAS is described in detail Douthwaite et al. (2015).

AAS was an outlier within the portfolio of 15 CGIAR Research Programs in adopting PAR as a central research methodology and using it to determine research priorities, rather than predetermining these before work started. As the program began implementation, the differences became clearer and concerns began to be raised at the CGIAR system level as to whether this was the sort of research the CGIAR should carry out (pers. comm. Wayne Powell, CGIAR Chief Scientific Officer, October 2014). In 2015, after steep funding cuts, the CGIAR decided to close two CGIAR Research Program, one of which was AAS. The reason given for this decision was poor performance against three criteria: a bibliometric analysis of science quality; a performance rating and anticipated performance (CGIAR, 2016). The latter received a failing grade, and was based on two inputs, one of which was a review by the CGIAR's Independent Science and Partnership Council (ISPC) of the AAS proposal to extend its work for eighteen months from mid-2014 (ISPC, 2014). The ISPC critiqued AAS for being an experiment in development, for being unclear about its technologies and for using a theory-based evaluation approach that did not require the use of control groups (ISPC, 2014). The critique can be understood as the ISPC evaluating AAS against the mainstream view of a CRP – a program that develops technologies for which treatment effects can be assessed by giving some villages the treatment and others not, and measuring the difference. AAS had failed to communicate its complexity-aware approach and results in a way that decision-makers in CGIAR found convincing.

The program closed in early 2016 after four years of a planned twelve-year lifespan. This created an arbitrary end-point in each of the cases, as the respective innovation processes were still mid-course at the time. For this reason, in each case we report on outcomes and emerging impact pathways that were able to be documented by AAS program staff before the closure of the program; however, these are inherently early-stage.

The Cases:

Case 1: Improving post-harvest fish processing in Zambia[3]

As a landlocked country, Zambia obtains its fish products from inland waters including lakes, rivers, and fish ponds, which are typically distant to major markets for fish. With lack of ice in fishing boats, long travel times to market under hot sun with no refrigeration, and handling practices which expose fish to insects, rodents, and contamination, spoilage of fish is a common and costly problem in Zambia as it is in neighboring countries as well. It is estimated that nearly one third of the total biomass of fish harvested in Zambia is lost due to various types of post-harvest loss and mismanagement (Béné, 2011), reducing the amount of fish available to consumers and contributing to food insecurity. Furthermore, when fish reaching the market has been degraded in quality, it reduces the prices customers are willing to pay and represents significant lost income to fishing families, processors, and traders.

Challenges in the agricultural system

These challenges, which are common throughout Zambia, are prevalent in the Barotse Floodplain, an area located in the upper Zambezi river where AAS established its program hub in 2011. This area contains a fishery of around 80 species and employs an estimated 4,350 fishers (Department of Fisheries, Zambia, 2012), with several times this number engaged in the value chain. Due to the lack of cold chains, fresh fish is processed in the Barotse using sun-drying and smoking, both of which produce brittle fish that are easily damaged in packing and transport, while being susceptible to loss from insects, which lay their eggs in the fish while it is drying. Insects and rodents also eat dried fish in storage and to prevent this, some processors use toxic chemicals to protect the fish and prolong its life.

In addition to the substantial challenges related to post-harvest spoilage and inadequate processing methods, a value chain needs assessment conducted by AAS in 2013 identified falling fish catches in the Barotse Floodplain as another issue placing pressure on the fish value chain (Longley et al., 2016). The study identified, overfishing, a failure to respect a fishing ban during fish breeding season, and the use of fishing nets (mosquito nets) with illegally small mesh size the main reasons given.

The research engagement process

The AAS team began its engagement in the Barotse floodplain with a scoping phase that identified a compelling development challenge facing the floodplain and stakeholders with responsibility and interest to tackle it (AAS, 2012). This so-called "hub development challenge" was "to make effective use of the seasonal flooding and natural resources in the Barotse floodplain system through more productive and diversified aquatic agricultural management practices and technologies that improve the lives and livelihoods of the poor" (Douthwaite, et. al. 2015, p. 63). There followed a stakeholder consultation workshop in June 2012, in which identified stakeholders from the floodplain, including community, government, research, NGO and private sector representatives, identified opportunities to tackle the challenge. Subsequently, AAS staff conducted community-level engagement and visioning as well as village-level action planning in 10 communities between August and September 2012, leading to a program design workshop in October 2012, facilitated by the first author. The purpose of this workshop was to identify how hub-level stakeholders could best support priorities that had been established by community members while also meeting

[3] A previous version of this case was written by Conrad Muyaule and Catherine Longley (WorldFish program staff), and published by Douthwaite et al. (2015) in the AAS Working Paper *Research in Development: Learning from the CGIAR Research Program on Aquatic Agricultural Systems*.

opportunities identified during the stakeholder consultation workshop. One agreement was for AAS to set up a fish value chain initiative, which included a value chain needs assessment study conducted from May-August 2013.

During this same period, AAS set up a fish value chain working group to guide analysis of the study results and inform next steps. This working group had 30 members and included participants from the traditional local authority (Barotse Royal Establishment), the Government of Zambia, NGOs, market development organizations, fish traders, and providers of services and inputs to the value chain. Following completion of the value chain needs assessment, a participatory planning workshop was conducted in September 2013. This workshop included members of the value chain working group as well as community members from the fishing camps that had been surveyed and from the 10 AAS focal villages. During the workshop, participants formed into three interest groups based on the top three priorities that emerged during the workshop: 1) fisheries co-management; 2) cooperatives, associations and access to finance; and 3) postharvest processing (Douthwaite et al., 2015, p. 64).

Following the workshop, the fish value chain working group members met and agreed to form themselves into an innovation platform – that is to form and motivate a number of interest groups that would periodically share the results from their respective PAR processes. AAS hired a value chain coordinator to set up the platform and to convene regular joint reflection and planning meetings. The members of the three interest groups were then invited to submit proposals to AAS regarding how they wanted to pursue their interests as part of the innovation platform. In October 2013, the members of the postharvest processing interest group submitted a proposal to AAS to work on fish salting as a potential approach to reduce post-harvest loss. The group included processor-traders and trainers from the Department of Fisheries who had some existing experience in processing and trading salted fish, which was uncommon at the time in Zambia but produced in DR Congo and Angola where there is an established market. During a proposal development workshop facilitated by AAS, the Principal Fisheries Officer in the Department of Fisheries provided training to group members on drying and handling salted fish, and the group decided to rename itself the Salted Fish Participatory Action Research (PAR) Group.

By this point, the group had grown to include 20 members from a diverse range of stakeholder groups. These included 12 fish processor-traders, three representatives from the Department of Fisheries, a nutritionist from the Ministry of Agriculture, one staff member from Caritas-Mongu (a local NGO and AAS partner), two representatives of the Barotse Royal Establishment, and one representative from Nono Enterprise, a private cold storage company. The group was convened and facilitated by the WorldFish AAS value chain coordinator and met quarterly to develop the approach to salting fish. The group's first steps were to try different fish salting and drying methods. Based on these initial experiments, they decided to recommend "one part salt to three parts fish" and the use of a slanted drying rack and the removal of gills as the preferred method. In March 2014, AAS convened the first fish value chain innovation platform meeting and invited the salted fish PAR group to present their work to date.

During subsequent discussions, and based on the suggestion of AAS staff, PAR group members agreed to introduce fish salting into the AAS focal communities and work towards developing a market for the product. However, it was noted that the safety of salt levels in the fish had not yet been verified, the market for salt fish still needed to be identified and the profitability needed to be determined. As a first step, in July 2014, some fish traders from the group took the initiative to display their salted fish at the Provincial agricultural show.

Unexpectedly, all the fish was purchased and some customers subsequently went to the traders' association store to find more. Since salted fish in Zambia is associated with Congolese and Angolan traders and since this was the salted PAR group's first experience demonstrating locally salted fish, they were surprised by the strong local demand for the product.

Following this experience and receiving a training from AAS in participatory action research (PAR) cycle (plan, act, observe, reflect), the salted fish group launched a PAR process involving four fishing communities in the AAS focal area. The group formulated a set of research questions, starting with an overarching question regarding the viability of salting fish as a means to deal with fish that would otherwise have to be sold very cheaply or go to waste. Within that, the group specified more detailed questions covering four areas: the profitability of producing and selling salt fish; the optimum storage and transport conditions; the demand and supply of salt fish; and how well the recommended fish salting and de-salting method would work. Starting in October 2014, group members began conducting activities in the focal communities, including how to salt and de-salt fish, cooking demonstrations on how to use salted fish, and taste testing to determine appropriate salt levels in the fish.

These activities were carried out jointly by fishers, processor-traders, and researcher members of the group, under the supervision of the Department of Fisheries members. In this process, the trainers discovered that a small percentage of community members already knew how to salt fish through their interactions with Congolese buyers. The PAR group members invited them to join the training efforts and help teach others in the community. By April 2015, the salted fish PAR group had grown to 42 members, including 22 members of fishing communities and all group members knew how to salt fish and how to sell it. Furthermore, the traders in the group guaranteed that they would buy any fish that group members salted. AAS program staff anticipated that in mid-July 2015 the PAR group members would start salting their fish; however, a particularly low fish catch led to a delay in implementing this plan. Members of the PAR group attributed the low fish catch to overfishing in general, and failure to implement a fishing ban during previous breeding seasons in particular.

Figure 1: Timeline of key events (events in black, significance in grey)

Outcomes and emerging impact pathways

Through an outcome evidencing process conducted between July and November 2014, AAS program staff identified four emerging impact pathways by which the program was contributing to change, one of which was improved fisheries management. None of the pathways had been specifically anticipated by program staff from the start; all had emerged from dynamics put in place through the RinD process. Through the processes of documenting, outcome evidencing, and writing up the salted-fish case, the following outcomes were identified as emerging from the work to improve post-harvest fish processing in Zambia.

1. The identification of a locally-adapted fish processing method

The development of a locally acceptable and replicable method of processing fish was one of the objectives of the research process, and by mid-2015 this objective had been accomplished. By engaging directly with fishers, processors, traders, and members of the Department of Fisheries who had prior experience in fish processing methods, the salted fish PAR group was able to relatively quickly identify an alternative to the traditional methods of sun drying and smoking and develop this method to the point that it could be used to produce dried fish that would be desirable to local consumers. The development of a method of processing fish with salt contributes to an impact pathway of reducing post-harvest losses in the fish value chain, one of the priority goals established by the project through consultation with stakeholders.

2. The development of a value chain for salted fish

In addition to developing a technical solution to the problem of post-harvest spoilage of fish, the salted PAR group assembled the basic components of a value chain for salted fish, including producers who knew how to use the method, traders who were aware of the product and interested to buy it, and end-consumers who knew how to cook with the salted fish and were willing to buy and consume this product. This value chain development occurred alongside the research process and as a direct result of the engagement of various stakeholders, such as fishers, processors, traders, and consumers, in the PAR process. The development of a local value chain for salted fish contributes to an impact pathway of increased earnings for fishers and processors (as a result of selling higher-quality fish) and improved food security for community members as more fish is able to make it to market undamaged.

3. The creation of a new multi-stakeholder platform capable of facilitating innovation processes

Another outcome area which formed part of the program's strategy was the successful creation of an innovation platform (multi-stakeholder group) that was capable of engaging in and leading local innovation processes related to the fish value chain. The fish value chain innovation platform supported several multi-stakeholder groups at the community level, including the salted fish PAR group. The platform provided a neutral and "safe space" within which stakeholders could build relationships and engage in joint work, directly enabling and contributing to the outcomes below.

4. The improvement of relationships among stakeholders in the aquatic system

An outcome of the research process which was not anticipated by AAS program staff was an improvement in the relationships between two groups of stakeholders in the aquatic system, namely the staff from the Department of Fisheries and trader-processors of fish. Prior to working together in the PAR group, trader-processors and fishers viewed the department staff as "persecutors" due to their efforts to enforce seasonal fishing bans during breeding season, a key component of sustainable fisheries management. Through their close interactions during the PAR process as well as innovation platform meetings, fisher-processors started to understand the importance of sustainable fishing practices and the relationship between these stakeholders improved considerably, to the point that trader-processors in the PAR group started to persuade their peers that the fisheries staff were "not the enemy, but rather a user-friendly service providing guidance and education on how to conserve fisheries" (Douthwaite et. al 2015 p. 66). This growing mutual understanding led directly to the outcome described below, which was also unanticipated by AAS staff but proved to be one of the most important impact pathways emerging from the project.

5. Increased consensus around the need for sustainable fisheries co-management

As a result of increased trust and improved working relationships developed through their interactions in the PAR group and the innovation platform, trader-processors went together with staff from the Department of Fisheries to fishing communities to explain the importance of allowing time for the fish to breed and to publicize the reasons for the fishing ban. With their newfound understanding of the importance of the fishing ban and their stronger working relationship with department staff, trader-processors were able to advocate for the fishing ban to their peers in fishing communities and work towards building a greater understanding at the village level regarding the importance of sustainable fisheries co-management. Despite being unanticipated, these outcomes was highlighted by program staff as the most significant because it contributes to the outcome trajectory of improved fisheries management identified by outcome evidencing as a way the program is starting to address the ambitious hub development challenge agreed by stakeholders at the beginning of the project.

Case 2: Rehabilitating abaca in the Philippines[4]

The Philippines is the world's largest producer of abaca, a relative of the banana plant used primarily to produce cordage, pulp, fiber, and paper. Over 1.5 million Filipinos depend on the abaca industry for their livelihoods (PhilFIDA, 2013), but in the 1990s an abaca bunchy top virus (ABTV) epidemic decimated production in many of the prime abaca-producing provinces. Some of the hardest-hit provinces were within the AAS hub, located in the Visayas-Mindanao (VisMin) region, a marine triangle in central Philippines. Southern Leyte, one of eight AAS focal areas within the hub, harvested just 954 metric tons of abaca in 2013 compared to 8,491 metric tons harvested in 2005 (PhilFIDA, 2013) and in 2014 was 12th out of 15 major abaca production areas, down from 2nd before the infestation. At current prices, a ton of abaca is worth US $1,100, so this decreased production represented a major income loss in a region where many farmers subsist on $1.50 daily income.

Challenges in the agricultural system

Support from the Philippines government for tackling ABTV during the 2000s was directed to programs that focused on eradicating infected plants. However, these programs lacked community support because farmers wanted to continue to grow abaca, not have it removed from their farms. In many communities in Southern Leyte, basic communication between farmers and the government had broken down due to a misunderstanding resulting from the fact that the local word for "medicine" was the same as "chemical," which the technicians used to describe herbicide. Farmers expected that their abaca plants would be treated with medicine and recover. Instead, technicians sprayed them with herbicide and killed them, along with all uninfected plants as well. This led to erosion in trust and poor implementation of replanting programs. Farmers were angry with technicians, and the technicians became afraid to go back into the communities. As a result, by 2013 many farmers in Southern Leyte were not practicing eradication voluntarily or regularly; nevertheless, they were still looking to the government to "do something" about the epidemic.

Government institutions such as Philippine Council for Agriculture, Aquatic and

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[4] A previous version of this case was written up by Lily Ann Lando and Maripaz Perez (WorldFish program staff), and published by Douthwaite et al. (2015) in the AAS Working Paper *Research in Development: Learning from the CGIAR Research Program on Aquatic Agricultural Systems*.

Natural Resources Research and Development (PCAARRD), Philippine Fiber Industry Development Authority (PhilFIDA), and National Abaca Research Center (NARC) had been working on abaca since the 1990s but were not working together or coordinating; instead, they saw each other as competitors for scarce funding and were jealous of their mandates. For their part, university researchers were focused on their respective R&D agendas, and tended to view farmers as a source of sample materials for disease management and for breeding work, using their fields for multilocation trials of varieties. Some research institutions held field days to show the farmers progress of their research work, but not to obtain feedback on whether the research was relevant or useful to the farmers in the first place.

Adding to the challenges, abaca farms in Southern Leyte were mostly located in marginal areas not easily reached by extension agents and researchers, yet if ABTV eradication is not performed correctly and sustained, the virus can easily spread since abaca reproduces through suckers, which carry the disease. All of the native abaca varieties favored by farmers at the time were susceptible to ABTV and hybrid varieties were not yet available for general release. Finally, since the aphid which spreads ABTV subsists on other crops commonly found in the *barangays* (the local word for communities), rehabilitating abaca requires collective action from farmers; they must all agree to eradicate crops that the aphids feed on in order to successfully control the spread of the virus.

The research engagement process

AAS program engagement began in the Philippines in similar manner to Zambia, based on tackling a hub development challenge identified during a scoping phase and agreed at a stakeholder consultation workshop. During the first half of 2013, AAS carried out community visioning, needs identification, and action planning in eight focal barangays within the VisMin hub region, selected on the basis of poverty and representativeness criteria. Two of the barangays in Sogod, Southern Leyte, identified the rehabilitation of abaca as their main dream and priority; villages expressed the view that there would be no more poor people if abaca was "given back to them" (Douthwaite et. al 2015, p. 59). In response, AAS commissioned the National Abaca Research Center (NARC), part of the Visayas State University (VSU) to conduct a rapid appraisal of the feasibility of abaca rehabilitation in this area (Tabada et al., 2013). The survey, completed in November 2013, found that the two barangays, Maac and Mahayahay, were losing USD 2 million per year as a result of the fall in abaca production from pre-infestation levels of 1,700 hectares per year to just 250 hectares per year in 2013. This represented a major drop in income for the local economy, given that about 6 of every 10 people in the *barangays* were living below the poverty threshold (Ibid, 2013).

The study found that it was possible to restore abaca in Sogod, but only with the strict implementation of eradication protocols, including eradicating alternate hosts to ABTV, and the use of resistant varieties. Based on this finding, the twenty or so farmers who had participated in the feasibility study in the two communities agreed to implement the recommended protocols and asked for planting material and financial support from AAS to do so. AAS researchers agreed to provide planting material in the form of tissue-cultured hybrid seedlings, but no money, as one of the principles of AAS's RinD approach was to motivate farmers' willingness to invest their own resources in their action plans. Farmers' organizations in both barangays created a committee on abaca and together with researchers developed an action plan for community-based abaca rehabilitation.

In May 2014, AAS staff monitoring the project found that none of the farmers had acted on their action plans to eradicate infected plants and plant the hybrid varieties. Through speaking with the farmers, staff learned that there were several reasons for this. Farmers had misunderstood the eradication protocol; they thought that they had to kill everything on their plots, which included coconut and karlang (a local variety of taro). Karlang was thought by the researchers to be an alternate host to the aphids that carry ABTV, but farmers were unwilling to eradicate it as it was their main alternate cash crop to abaca. Furthermore, farmers were unhappy with the hybrid abaca varieties provided and wanted seedlings of their traditional varieties, as they felt that these provided better fiber quality as well as more fiber than the hybrids.

To address this impasse, researchers from AAS and VSU organized focus group discussions with the farmers in May 2014. During these meetings, they assessed farmers' existing knowledge of ABTV through a pre-test, clarified the eradication protocol, and agreed to investigate whether the aphids found on karlang were the specific vector for ABT. If not, then karlang would not have to be eradicated as part of the protocol. For their part, farmers started discussing the inclusion of the neighboring barangays of Javier and Maria Plana in the abaca work. Since Javier is situated between Maac and Mahayahay, the farmers said that it should be included because any crop protection practices they implement will be useless if Javier plantations remain diseased. Also, the Mahayahay farmers shared that most of them had their abaca plantations in Maria Plana and so it would be logical to include Maria Plana in the program. They then took on the responsibility of talking to farmers in these two other *barangays*.

While the farmer's suggestion demonstrated an increased understanding of the epidemiology of ABTV, it also raised a new challenge: there was not enough tissue cultured planting material available for farmers in all four communities, due to the laboratory process required to produce it. After a series of conversations, researchers and farmers negotiated a seedling distribution system that could address this supply bottleneck. A first tranche of farmers would receive 50 seedlings each, with the agreement that they would repay the planting material in 4-5 months when their seedlings produced suckers. Each mother plant produces 3-6 suckers in that period, and each farmer agreed to repay with two suckers, giving 100 suckers back which could then be given to two other farmers to plant, until all members of the abaca farmers committee had received 50 seedlings each.

The engagement leading to this agreement proved to be a turning point in the relationship between researchers and farmers in this case. Farmers started to ask the researchers about conducting research on their own questions related to abaca and whether they could adjust the experimental protocols. One farmer suggested that he wished to conduct comparisons between his tissue cultured material and those growing naturally on his land which had been certified virus-free by NARC. Another farmer asked to change the research protocol by planting his abaca on the flat land closer to his house, which was easier for him to access than the hills where it is usually grown. He offered that he could then compare the performance of his plants on the flatland with his neighbor's plants on sloping land. AAS staff facilitated an agreement that both farmers and researchers would take actions based on each other's preferences and priorities, and agreed to meet quarterly. Some farmers decided to meet monthly as well, without AAS facilitation, to compare their data and share ideas, while VSU-NARC hosted 10 farmers from each barangay to visit their abaca hybrid research plots and attend a forum on abaca production technologies.

During this time, AAS staff realized that it was important to form a multi-stakeholder coalition around the abaca work. Building on a previous but now defunct coalition called ADMART (Abaca Disease Management and Research Team), AAS convened an initial meeting with stakeholders from academia, research organizations, national and regional agencies in July 2014. These included VSU-NARC, Southern Luzon State University, Sogod and Southern Leyte local government units, and regional line agencies including the Department of Science and Technology, Region 8 (DOST8), the Department of Agriculture Region 8 (DA8), and the Philippine Fiber Industry Development Authority (PhilFIDA). These groups were brought to the table through the convening power of the AAS country program leader, who had strong personal connections through her previous position in the Department of Science and Technology, and the director of NARC, Dr. Gaspasin, who had taught most of the people in the room at some point. Stakeholders present at the meeting agreed that a coalition should be reconvened to enable the various agencies to work together.

Building on this agreement, AAS organized an abaca stakeholder consultation workshop in September 2014, with an even larger range of stakeholders. Agencies presented their work on abaca to each other, and engaged in an exercise to describe future scenarios for the abaca industry in the Philippines. During these conversations, the agencies decided to formalize a new coalition to replace ADMART. In a departure from the norm, they decided to begin working together immediately using their current programs and budgets, rather than waiting to obtain a common new source of funding. PCAARRD agreed to include Sogod in its target sites for abaca research and to set up a community-based science and technology farm, while PhilFIDA agreed to collaborate with DOST 8 to channel the distribution of tissue-cultured planting material to Sogod to support the seedling distribution scheme.

Following this meeting, VSU-NARC and DOST8 contributed 4,000 tissue-cultured seedlings and PhilFIDA provided another 1,500 seedlings to the distribution program, which provided a first group of 71 farmers from Maac and Mahayahay barangays with the agreed-upon 50 seedlings each. Soon after, a second tranche of 51 farmers from Maac and 5 farmers from Mahayahay were also able to receive 50 seedlings each. Two farmers from Javier and three from Maria Plana received 250 seedlings total and by October 2014 this initial group of farmers had planted their disease-resistant abaca. By January, farmers in this first group reported that their plants had produced suckers and started sharing their data and results with AAS researchers.

On February 2, 2015, the new multi-stakeholder Abaca Coalition organized a formal launch. In keeping with local tradition, members organized a motorcade with a banner showing the logos of the member agencies and the tagline: *Kauban ta sa Coalition Abaca* (we are part of/we support the Abaca Coalition). Community representatives from Mahayaha hired a van, the Maac farmers brought their motorcycles, and the representatives from Javier and Maria Plana rode in the official agency vehicles. An additional 4,000 seedlings were distributed to farmers at this event, including farmers from Javier and Maria Plana. Later that month, PCAARRD delivered a check for the first tranche of the budget for the Science and Technology Community-based farm in Sogod, amounting to over 2 million PhP (US$ 42,500). PhilFIDA also made a commitment to provide 5,000 additional tissue-cultured seedlings through June of 2015 and potentially another 5,000 through December, representing a contribution of PhP 250,000 (US$ 5,300).

As of the end of February 2015, farmers were conducting farmer-led field trials of tissue cultured native varieties, continuing to participate in the seedling distribution system, and developing a strategic communication campaign for abaca rehabilitation, which included materials to popularize and spread the eradication protocol throughout the communities. In addition, farmers agreed to serve as resource people in a radio communications campaign which was planned to be organized by university-based researchers. The next steps that were being planned by AAS program staff at the time the program was closed included bringing farmers and processors/end-users of abaca together to start working on the development of an inclusive value-chain for abaca.

Figure 2: Timeline of key events (events in black, significance in grey)

Outcomes and emerging impact pathways

Outcomes related to this case were mapped, described, and verified by AAS staff through an outcome evidencing process conducting between March and October 2014 and resulting in the publication of an Outcome Evidencing Report for the VisMin Hub published by World Fish in March 2015 (Paz-Ybarnegaray 2015). Through an analysis of this report and the details of the case, we have identified five outcome areas below, which contribute to two major impact pathways. The first impact pathway is around the successful rehabilitation of abaca, a major source of income and livelihood for the region, and the second involves the strengthening of the capacity of local system stakeholders to take effective joint action towards the realization of common objectives and local development priorities.

1. Farmers in four communities working to rehabilitate abaca

Prior to the participatory research effort, farmers were not implementing eradication protocols, yet nevertheless dreamed of restoring their abaca production. By early 2015, over 200 farmers from the four barangays had implemented the eradication protocol, cleared their land of infected plants, and received and planted virus-free tissue-cultured seedlings. Farmers were becoming more open to the use of hybrid seedlings and were demonstrating initiative in terms of persuading their neighbors to join the eradication protocol, proposing their own research questions, leading field trials of native varieties, organizing their own meetings to share results and contributing to communication campaigns. These outcomes resulted not only from farmers' increased knowledge regarding eradication and rehabilitation protocols, but also from their hands-on engagement in the research process, their enhanced research skills, and –crucially--their newfound motivation to engage in and enlist others in the rehabilitation work, kindled by a growing realization that they possessed the ability collectively to achieve the goals they had set out for themselves.

2. Increased supply and access to disease-free seedlings

One of the bottlenecks previously preventing farmers from engaging in abaca rehabilitation was lack of access to disease-free plant material. Several factors came together to enable stakeholders to overcome this bottleneck. Agencies that had previously not been working together joined forces through the Abaca Coalition to contribute from their own budgets and make tissue-cultured seedlings available to the communities. Farmers and researchers, through ongoing interaction, conversations, and negotiations, developed a creative distribution strategy, which facilitated the rapid multiplication of the stock of disease-free plant material. This increased access to virus-free abaca enabled farmers in the initial two *barangays* to implement their action plans to rehabilitate their farms, while also making it possible for them to enlist farms in the neighboring two *barangays* in the rehabilitation effort, increasing the chances of sustained success for the eradication and rehabilitation effort.

3. Farmers and researchers conducting joint research and development

While the relationship between farmers and researchers started with misunderstandings, over the course of the project, researchers were able to build trust with farmer and farmers were able to influence the research process to align it better with their priorities. Initially, researchers wanted farmers to eliminate karlang and farmers wanted to rehabilitate abaca using their preferred native varieties, Inosa and Laylay, which were susceptible to ABTV. Through ongoing dialog, by the end of the project, researchers and farmers had agreed to trial disease-free tissue cultured materials of both native and hybrid varieties to test whether this reduces the chance of disease spread and how the fiber quality of the hybrids compares to the that of native species. Farmers were actively involved in the research process, proposing research questions and serving as partners in the research process through tracking their results and sharing them with other farmers and researchers. Engaging farmers as co-researchers built the capacity of local system actors to innovate, both in terms of developing suitable disease-free plant material and creating a distribution system.

4. New and improved relationships between system stakeholders

In addition to overcoming technical challenges related to the correct implementation of eradication protocols and the supply of disease-free seedlings, the research process built new linkages between actors who were not previously working with each other, while improving relationships between stakeholders who had a history of prior engagement. Before the launch of the Abaca Coalition, PCAARRD was not working with PhilFIDA in Southern Leyte, and PhilFIDA saw NARC as a competitor. A representative of PhilFIDA recalled that "we were isolated from the other groups, particularly NARC. We had no communication, no exchange of ideas, and we were not aware of their research outputs" (Paz-Ybarnegaray 2015, p. 5). The Department of Science and Technology (DOST) was not working on abaca at all, and VSU-NARC was not working in Sogod, although the town was only two hours away by bus.

Through their engagements in the abaca rehabilitation process, stakeholders experienced a shift and improvement in the dynamics of their relationships, from suspicion to greater mutual appreciation and from a competitive stance to a climate in which partners were voluntarily contributing funds from their own budgets to support a common agenda. These strengthened relationships and improved linkages were identified by AAS program staff as a key factor contributing to the impact pathways of successful abaca rehabilitation, a key factor in the formation of local stakeholder groups capable of sustaining this work as well as progress towards other local development objectives.

5. The creation of stakeholders' groups capable of mobilizing collective action

As of February 2015, three new stakeholder groups had been created through the research process, each of which was contributing in significant ways to the abaca rehabilitation effort. The first two groups were abaca committees established within the Farmers' Associations of Maac and Mahayahay barangays. The Maac Abaca Committee contained 85 members, the Mahayahay Abaca Committee contained another 50 members, with a research specialist with the DOST 8 (which previously had not engaged in abaca work) leading the coordination between groups. The third new group was the Abaca Coalition, which had grown to include representatives from 16 national and local-level with an interest in abaca, including three universities engaged in abaca research, national government agencies, regional line agencies, local government units, media, the local chamber of commerce and industry representatives from the private sector.

This platform facilitated linkages between various stakeholders, assisted in building visibility and community buy-in for the abaca rehabilitation work, and—crucial to the success of the project—enabled an agreement among stakeholders to provide access to the tissue-cultured plant material needed in order to implement the rehabilitation plan. This contributed both to the impact pathway of abaca rehabilitation as well as a new and unanticipated area of impact emerging from this case: namely, the capacity of system stakeholders to mobilize existing resources and take effective joint action to achieve common development objectives.

Cross-Case Findings

In order to develop a middle-range ToC which can describe how the RinD approach worked in both cases, we must identify the common outcomes to which the program contributed, the program inputs that were provided, and the causal mechanisms which were triggered and/or harnessed by this program activity.

Outcomes

In both cases, the AAS staff implemented the same programmatic approach – the RinD approach. Table 2 summarizes the outcomes identified in both cases as well as the common mechanisms which contributed to bringing about these outcomes.

Table 2: Comparing case outcomes revealing common mechanisms

Case 1: Improving post-harvest fish processing in Zambia	**Case 2: Rehabilitating abaca in the Philippines**	**Common mechanisms**
The development of a locally-adapted fish processing method	Farmers in four communities working to rehabilitate abaca	- Identification of an existing, commonly-experienced need triggers engagement and action; - Participatory research, joint technical work and capacity-building lead to identification of suitable technical solutions
The development of a value chain for salted fish	Increased supply and access to disease-free seedlings	- Early, tangible results build motivation among stakeholders to engage with (and stay engaged with) the process 4. Engagement leads to collaboration among key actors

		who previously were not working together
The creation of a new multi-stakeholder platform capable of facilitating innovation processes	Farmers and researchers conducting joint research and development	- AAS uses convening power to bring key stakeholders together for initial meetings and participatory workshops Stakeholders realize areas of shared interest and propose ways to continue working together.
The improvement of relationships among stakeholders in the aquatic system	New and improved relationships between system stakeholders	Frequency and quality of engagement builds mutual understanding and trust; Tangible results of collaboration reinforce the benefits of working together.
Increased consensus around the need for sustainable fisheries co-management	The creation of stakeholders' groups capable of mobilizing collective action	- AAS' limited role (of process facilitation) leaves space for local actors to take ownership of the process and generate next steps and new initiatives; - Progress on technical challenges inspires confidence to address additional issues.

In both cases, RinD led to motivation and agreement between stakeholder groups to work on a common issue. Joint technical work and capacity-building on this issue led to improvements in technical options to address the challenge and in the value chains needed to put these options into use. This work contributed to improving relationships among system stakeholders, and these improved relationships in turn played a critical role in facilitating next steps in the work. As collaboration continued, stakeholders built social capital and a set of process skills that allowed them to take effective collective action and pursue other mutually-beneficial local development objectives.

Inputs

In addition to outcomes, another essential component of a theory of change are the inputs provided by a program or intervention. Consistent with the conceptual framework used in this paper, we take as given that programs do not bring about change directly through their inputs and key activities, but rather through the ways in which program participants and stakeholders interpret and use what the program provides (Pawson 2013). In order to construct a ToC to model these cases, we must therefore identify what was provided by AAS (through the RinD approach) which was used by participants and stakeholders in ways that contributed to achieving the outcomes described above. By comparing the two cases as well as re-analyzing the synthesis chapter of the program report (Douthwate et. al. 2015, pp. 81-87) we can identify six key input that were used by program participants and stakeholders in the process of achieving key outcomes.

1. A process to engage stakeholders in developing a joint vision of success

In both cases the program engaged with stakeholders to identify and agree on a pressing development challenge facing a major aquatic agricultural system in the system. Staff used this to identify a set of focal communities in which it then worked with groups to identify their vision and steps to achieve it. Community priorities were communicated back to hub-level stakeholders in process to agree the main initiatives upon which the program would work, e.g. improving the fish value chain in Zambia and rehabilitating abaca in the Philippines. This process took at least eight months in each hub but enabled the identification of attractors relevant to multiple groups of stakeholders.

2. A process to identify an issue of common interest

In each case, the initial motivation of stakeholders was kindled through a process designed to identify an area of common interest and concern, shared by at least two different stakeholder groups in terms of function (e.g. researchers and farmers). Identifying this area of shared interest took several months but proved key to building trust and motivation, given the work received little external funding beyond process facilitation.

3. Facilitation of engagement between existing stakeholders and linkages to new stakeholders

The facilitation activities provided by program staff included facilitation of workshops, after action reviews and other events which brought key stakeholders together. The facilitation role played by staff also included facilitation of community-level PAR processes. The quality of facilitation in terms of the frequency of meetings and the successful management of conflict was an important factor in maintaining participants' motivation to remain engaged for sufficient periods of time to enable the identification of areas of mutual common interest among at least two key stakeholder groups.

4. "Safe space" for stakeholders to build trust and develop working relationships

Facilitation processes in which program staff played the role of an "honest broker" helped groups and platforms to become 'safe spaces,' where different stakeholders could tackle common problems and build stronger working relationships. Stakeholders and program participants were able to use the trust and social capital built in this way to explore initially agreed-upon research questions and to identify new and more complex ones, e.g. moving from how to salt fish to how to co-manage fish stocks more sustainably.

5. Opportunities to "learn by doing" supported by coaching

Participants found opportunities to learn new technical and soft skills through the process of carrying out research together such as farmers learning how to carry out field trials, and group members learning to take on more responsibility. Coaching played an important part of this "learning by doing" with researchers coaching farmers in research methods and AAS facilitators coaching group leaders in the skills and principles required to carry out quality PAR.

6. Knowledge inputs with high relevance to local stakeholders

The program also provided the inputs normally expected of a research initiative, such as needs assessment surveys, feasibility studies, information to answer key questions of local stakeholders and access to new technology. New knowledge and technology was tested in the joint field trials and subsequently adopted by farmers if successful. Researchers used survey and study data to pursue their research and publication plans.

A Theory of Change (ToC) to describe how RinD worked

The common outcomes and inputs described above allow us to develop a middle-range theory of change (ToC) to describe how the RinD approach worked, shown in Figure 3. Like most ToC, this is comprised of a chain of inputs, outputs, and outcomes which are connected by arrows to suggest causal connections, which can be tested empirically through evaluations and research. This model derives its hypotheses regarding causal connections from evidence at the program level (gathered through the outcome evidencing process described earlier), and like most standard ToC, uses this evidence to create a simplified causal narrative that can graphically depict a working theory regarding how a program creates impact. However, unlike standard ToC, the model we present follows the format of causal loop diagrams (Team TIP, 2011) rather than the more familiar, linear "if/then" formulation of conventional ToC. Causal loop diagrams allow a non-linear depiction of causality (e.g. allows for self-reinforcing and dampening loops) and can incorporate insights from complexity science and systems dynamics referenced previously.

The model (Figure 3) depicts key initial program activities (boxes 1 and 2), and the resulting initial outcomes of these activities (boxes 3 and 4) which lead to increases in the motivation of system stakeholders to engage in the subsequent PAR process. The motivation of system actors, combines with a set of inputs from AAS in the form of facilitation (6), technical skill training (7), hands-on experience and exposure to a set of soft skills such improved leadership (8), links to other actors and the opportunities that this affords (9), and recognition of their work (10) enable the PAR process to function (box 5). This deeper and more intensive level of program activity leads to the generation and use of solutions to technical (11) and complex (12) challenges as increased capacity for local development (13) grows. Complex solutions include the development of new ways of working and new institutional arrangements (e.g. new groups and platforms).

Figure 3: Causal model (ToC) of how the RinD approach worked

There are a number of self-reinforcing loops shown in the model which seek to depict dynamics of learning and adaptive change present in the cases. As groups of farmers and other local stakeholders built their capacities for research, technical R&D, and effective joint action, they began to identify technical solutions to the challenges facing them (box 11), for example finding a way of salting fish or establishing whether abaca varieties were disease resistant, as researchers claimed. Later, as the groups strengthened, they began to see they could tackle deeper and more complex challenges (12), for example tackling overfishing in Zambia or improving farmer – researcher – system stakeholder interaction in the Philippines.

These solutions produced benefit streams that motivated further efforts to improve and find new solutions, which in turn continued to build the capacity of participants and the groups (11). This capacity, which can be understood as the capacity for the local system to innovate, included increases for both individuals and groups in:

- New technical skills, e.g. how to carry out experiments and analyze the results
- Self- and collective- efficacy
- Ability to assess options and identify key system challenges
- Ability to go through iterative visioning, planning and reflective learning cycles
- Capacity to link to other actors and to use linkages strategically in support of plans
- Enhanced capacity for effective collective action

Like all ToC, this one contains several assumed "contextual factors" that are key elements of the model. The first is that a development challenge exists which is relevant to all stakeholders and around which they can find common purpose. The second is that participants are willing and able to work collectively in groups towards that common purpose. In some highly-intervened areas, for example parts of Bangladesh, farmers have become fatigued by a continual cycle of projects wanting to facilitate groups and participatory approaches (Conway and Mustelin, 2014). The third assumption, which is perhaps the most important, is that actors facilitating the engagement process are able to do so in a way that is perceived as "neutral" and trustworthy by participants, and for a long enough period of time to allow groups to find their own momentum and begin to drive the process themselves. In the two cases presented in this paper, AAS staff highlighted that one of the ingredients of success was the willingness of staff to spend extended periods of time (up to a month) in the focal communities and maintain the engagement process through regular meetings, workshops, and reflection sessions. This provided the time required for groups to begin to define their own work, fueled by mutual interest and a growing sense of collective efficacy.

Discussion:

The ToC presented above differs from the conventional pipeline ToC in agricultural research in important ways, including its starting assumptions, its component parts, and the story of causation linking them together. More importantly however, it also leads to a different set of questions that evaluators, researchers, and decision-makers can ask when seeking to understand if a complexity-aware intervention is producing "impact." In the dominant "pipeline" ToC, development impact is understood to be achieved through the sourcing, development, testing, adoption, and widespread dissemination of particular innovations and technologies; the impact on people's lives is understood to result primarily from the use of these "breakthrough development innovations" which include devices, (e.g. solar lanterns); technologies and platforms (e.g. mobile money) and new practices (e.g. conditional cash transfers) (USAID, 2015). Evaluations based on the pipeline TOC put the emphasis on assessing first the adequacy (suitability, scalability, novelty, etc.) of the "solution" generated by the research process, second and perhaps most importantly, the number of "beneficiaries" who have adopted the solution, and finally the livelihood or wellbeing impacts to those beneficiaries of the new technology, innovation, or research output.

In contrast, the complexity-aware TOC we have developed shows that impact is achieved through building the capacity of the rural innovation system to innovate, in part through the development of technical solutions, but also through the development and strengthening of key types of infrastructure and capacities (such as new platforms, networks, skills, and ways of working). Hence, we can model agricultural research for development as achieving impact through two interdependent impact pathways: the technology adoption pathway, described above, and an empowerment (or capacity) pathway (see Figure 4). In this overarching causal model under which our middle-range ToC sits, carrying out research to tackle technical issues (1), as part of the adoption pathway, is also an important way to build system capacity to innovate, if carried out collaboratively (2) and thus is a contributor to the empowerment pathway. Increased capacity to innovate contributes to better and/or faster rates of rural innovation (3) thus increasing the benefits from adoption of research technologies (4) and from other innovation processes addressing other issues. A self-reinforcing loop exists in which increased rate of innovation leads back to the development of new ideas, knowledge and/or technology, that in turn builds capacity to innovate, and so on. A dampening loop exists if the adoption of new technology leads to the loss of diversity and/or capacity (e.g. knowledge, skills, relationships) from which future innovation trajectories could emerge, such as the loss of local plant varieties, local knowledge and expertise, or low external input farming practices.

Figure 4: An overarching causal model showing agricultural research leads to impact through the action of two complementary impact pathways

This model shifts the focus of evaluation from questions related to a specific technical solution and the extent and impact of its adoption (although these questions remain) towards questions related to the quality and effectiveness of the innovation process and the resulting system capacities that have been developed. Since this alternate route to impact involves leaving stakeholders and program participants in the system better able to tackle both technical and complex challenges relevant to them, an evaluator would look for outcomes related to enhanced technical and adaptive capacities, as well as evidence of increased capacity for local development. Depending on the context, this might include questions related to the formation and functioning of groups and platforms designed to address local challenges and the effectiveness with which they are doing so, the nature and results of experimentation taking place, organizational leadership and effectiveness, and quality as well as extent of inter-system and intra-system linkages.

The evaluator may look for evidence of self-maintaining groups and entrepreneurs starting to drive local change processes, as well as adoption and spread of solutions to technical and complex issues developed by participating and spin-off groups and individuals.

He or she will want to see the extent to which individuals and organizations are joining the groups and platforms and investing in their own resources in them. In terms of initiative outputs, the evaluator would assess their merit less in terms of how they are judged by research peers (although within the CGIAR this remains important), and more on how they are being interpreted and used by intended and unintended users.

A complexity-aware ToC, therefore, can help a complexity-aware program to be evaluated against the types of results it is intending and designed to achieve. This can make the difference as to whether a program continues to be funded, or not. A complexity-aware ToC can also be useful for staff working within such programs, contributing to developing program-level monitoring, evaluation, and learning frameworks that more accurately reflect how programs work as well as the types of outcomes and impacts they typically produce. Given increasing calls for "reflexive M&E" and embedded, real-time learning and reflection within complex system-change initiatives (van Mierlo et al. 2010), complexity-aware ToC can offer frameworks to guide these efforts which may be more relevant and useful to program staff than existing linear logic models.

Researchers interested in how agricultural research works, or not, to bring about change can also benefit from working with ToC that seek to more accurately model the dynamics of change in complex agricultural innovation systems. In the same way that complexity-aware ToC lead to a different set of evaluation questions from conventional logical frameworks (logframes), they also generate a different and potentially fruitful set of both descriptive and causal research questions related to understanding the dynamics of specific change processes involving agricultural research, as well as deriving common patterns across them. Complexity-aware, middle-range theories of change transcend the individual program level and therefore have the potential to apply to a wider set of interventions seeking to produce sustainable development impact through stimulating local innovation and change processes.

As such, the model we develop in this paper responds to calls from within the recent literature to develop (and/or adapt) middle-range theories to describe how interventions operating in contexts characterized by complexity produce system change and impact (Pawson, 2013; Arkesteijn et. al. 2015). Compared to program-level theories of change, middle-range theories better describe contexts characterized by complexity because they acknowledge that outcomes result from a broader range of interacting factors, including, but not limited to how stakeholders engage with program interventions. Programs can—and often do—play a role in contributing to these outcomes and program staff, organizational leaders, and funders have a practical need to be able to model, test, and articulate the ways in which their efforts are contributing to (or designed to contribute towards) broader beneficial systems change. For this reason, we seek to encourage the development and formulation of ToC that can better reflect the realities of complex contexts and complexity-aware interventions, rather than suggesting that in these contexts ToC should be abandoned altogether in favor of adaptive, real-time evaluation and learning approaches such as Reflexive Monitoring in Action (Arkesteijn et. al. 2015) and Episode Studies (Carden, 2009).

Conclusions

In recent years, there has been a growing call within academia and evaluation practice for programming and monitoring and evaluation that is both complexity-aware and reflexive, particularly within the domain of agricultural innovation systems, which are increasingly understood to possess the characteristics of complex, adaptive systems (CAS). The necessity and usefulness of a complexity-aware evaluation approach has been effectively argued, and theoretical frameworks have been developed to guide and stimulate the creation of evaluation approaches that take complexity into account. However, this field of work is still nascent and has remained mostly at the theoretical and conceptual level, laying necessary foundations for the development of practice-oriented frameworks and tools to guide implementers and evaluators in adopting a complexity-aware approach in their program design and evaluation efforts. While some individual projects and programs have begun to develop their own internal complexity-aware evaluation processes, there are few, if any, examples in the literature or the public domain of evaluation frameworks (e.g. ToC, logframes) that integrate the insights from the emerging field of complexity-aware evaluation into their design.

This is the gap in both the literature and practice that this paper begins to address, by extending existing theoretical and conceptual work to develop an example of what a complexity-aware ToC might look like for a particular intervention which was explicitly complexity-aware in its design. This ToC offers a starting point for testing a different set of hypotheses than those which are embedded within the common, linear impact adoption pathway. It also suggests a different direction and logic for how ToC might be constructed for complexity-aware programs moving forward. When impact pathways can be modeled, their various causal connections and hypotheses can be clearly stated and empirically tested, which can inform the development of models that more accurately describe reality. We therefore see the ToC presented in this paper not as a definitive causal model of how the two AAS projects that were profiled worked, but rather as an example of how such models can be constructed which can lead to subsequent refinement, empirical testing, and improvement over time. Our hope is that this provides a pathway which stimulates the creation of better-fitting and more useful models that illustrate and communicate how complexity-aware interventions into AIS produce development impact for systems and their stakeholders.

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