METHODS AND APPROACHES FOR SCALING-UP THE POSITIVE BENEFITS OF CACAO AGROFORESTRY IN ECUADOR

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ABSTRACT

The analysis and findings presented in this project are the result of a comprehensive literature review and an engaged action-research process involving the Ministry of Agriculture and Livestock (MAG) in the Amazonian province of Morona Santiago, Ecuador. What prompted the action-research was an expressed and observed need to gather the views and feedback of beneficiaries and other stakeholders involved in two agroforestry programs of the Ministry. Therein, a rapid appraisal responded to the decision-makers' need for information to improve the development practice of Ecuador's public agricultural extension system.

The information presented here is the result of the triangulation of desk-based and field-based research methods, employed to gather and analyze information over a period of 10 months. The collection of primary data was conducted through Farm Transect Walks, Semi-structured Interviews, and some structured observation with/of government officials and a typology of farmers in four counties of the Morona Santiago Province. Most participants were either personnel or beneficiaries of the two main MAG projects related to cacao production in the Amazon, namely the *Agenda for the Productive Transformation of the Amazon* (ATPA) and the *Project for the Reactivation of Fine Aroma National Cacao* (PRCC). Additional interviews were conducted with key informants from the National Institute of Agricultural Research – (INIAP), provincial and municipal governments, the Ministry of Industries and Productivity, and the United Nations' REDD+ program in Ecuador (PROAmazonia). (See Appendix I for data collection instruments). A number of academic publications, professional reports, and

official extension materials from various institutions around the world were used to examine the Ecuadorian experience.

Project-specific results, analysis and recommendations of the rapid appraisal were presented in a technical report (in Spanish) to the Ministry of Agriculture and Livestock. In contrast, this document focuses on the larger implications of the appraisal results for scaling-up agroforestry in the tropics. It answers – at least in part – the important question: why have the positive benefits of agroforestry been difficult to scale-up?

Based on the case study and the literature, there are five types of barriers, with interrelated causes and effects, that block the scaling-up process of cacao production in an agroforestry system. These barriers are:

(1) Ideological barriers: a romanticized notion of agroforestry as a silver bullet and as a monolith, which ignores the ground-level tradeoffs involved in a typology of agroforestry configurations.

(2) Barriers in program management: the absence of adaptive management philosophies and methods that can work with the challenges of multi-variable agricultural systems, scientific gaps, socio-ecological uncertainty and climate uncertainty.

(3) Barriers for well-suited agroforestry design: Research & Extension (R&E) models with philosophy, structure and tools that mismanage the inherent challenges of designing complex agricultural systems.

(4) Barriers related to agroforestry management and pedagogy: Management regimes are a learning-based process. This process is not being facilitated by the current agricultural instruction methods, which remain blind to farmers' learning styles, blind to social equity and climate action.

(5) Systemic bottlenecks: barriers in agroforestry markets require concerted action from actors well beyond research and extension institutions.

In response to these barriers, I outline a handful of existing methods and frameworks that agroforestry development practitioners might use as resources. The biggest takeaway of this work is that scaling-up the positive benefits of agroforestry will require drawing from a variety of theoretical traditions and tools with different analytical scopes, on and off- farm. From land use practices and farming households, to front-line extensionists and management staff, all the way to the private sector, scaling-up agroforestry will require a systemic shift.

BIOGRAPHICAL SKETCH

Gloria “Ire” Burgoa is a Bolivian-American, agricultural development practitioner and a graduate student in the International Agriculture and Rural Development program. After receiving her degrees in Foreign Affairs, Gender Studies, and Anthropology from the University of Virginia, she served as a Peace Corps Volunteer in rural Panama. She has worked and/or conducted research in agroforestry extension in Panama, the Dominican Republic and Ecuador; and has consultant experiences for gender-focused projects with the Inter-American Development Bank and UNESCO. She currently conducts data analysis for the Cornell Farmworker Program in Ithaca, New York.

Ire is committed to agroecological, inclusive and interdisciplinary approaches to development.

Este trabajo va dedicado a las mujeres, hombres y jóvenes productores de las comunidades Quebrada Pinzón y Quebrada Plátano en Panamá. Fueron ellos los que más que nadie me enseñaron el valor de trabajar con las manos, y los que despertaron en mí una pasión por "caminar con piedras en el zapato" por entender realidades diferentes.

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CHAPTER 1

AGROFORESTRY AMBITIONS

Agroforestry Systems (AFS) have gained leverage in recent years as multi-functional land use capable of realizing more resilient socio-ecological systems (López et al., 2017). Often portrayed as viable technologies for ecologically intensifying food production, AFS are – in the most general sense – production systems that integrate forestry, agriculture and/or animal husbandry (P. Nair, 1993). These have been praised for mitigating climate change; enhancing ecosystem services; supplying farmers with food, fuel, and construction materials; diversifying farmers' economic portfolio in the face of market uncertainty; and even cultivating spaces for cultural transmission and recreation (Michon and De Foresta 1992; Buresh et al. 1996; Kumar and Nair 2006; Ong 2006; Jose 2009; Nair 2011; Bommarco et al. 2013; Lasco et al. 2014; Somarriba et al. 2017; Blaser et al. 2018; Gabriel 2018). Around the world, farmers have successfully employed this strategy of diversification since the Mesolithic period, managing timber, fruit and leguminous trees on the same plot, together with other annual crops and/or animals (Caballero-Serrano et al., 2016; Chepstow-Lusty & Jonsson, 2000; Dagar & Tewari, 2016; D'Apollonia et al., 2018; Jarrett et al., 2017; Kumar & Nair, 2006; Lindgärde et al., 2004).

To many, agroforestry is a silver bullet for the wicked problems our planet faces. But this paper speaks to an inconvenient truth. Why - despite the demonstrated benefits of agroforestry to farmers and nations- has scaling-up the benefits of these systems proven difficult?. For over a decade, advocates of tree-based, diversified cropping have been confronted with the reality that AFS are not always ecologically sound, productive, or efficient enterprises (Borremans et al.,

2018; Brandt et al., 2012; Chowdhury, 1999; Franzel et al., 2001; German et al., 2006a; Jacobi, 2016; Miller, 1999; Sanchez, 1995; Vaast & Somarriba, 2014a). In fact, meta-analyses of agroforestry practices show that these systems can yield a wide range of outcomes, from desirable ecosystem services to suboptimal and even detrimental effects for profits, farming livelihoods and/or ecological integrity (Coe et al., 2014; German et al., 2006b; Jose, 2005). The challenges involved in scaling-up *the positive effects* of agroforestry are the main topic of this project, elucidated by analyzing real life examples from Ecuador's cacao-based agroforestry programs in the Amazonian province of Morona Santiago.

The structural and functional complexity of agroforestry technologies, when compared to traditional agriculture, results in unique scaling-up dynamics in need of separate analysis (Mercer, 2004). Yet, there are few and far reviews that are agroforestry-specific and multidimensional (D. C. Catacutan et al., 2017; Coe et al., 2014; Franzel et al., 2001; Mukarutagwenda, 2018). One of the most useful reviews on the topic by Franzel et. al (2001) has identified ten key elements[1] that would enable the wide spread uptake of these technologies. More recently, the Agroforestry Network, a platform founded by Vi Agroforestry, has drafted the most comprehensive review to date of the cross-sectoral barriers[2] involved in scaling-up processes (Chapter 6). This project paper revisits and adds to the relatively scarce literature on the topic, drawing from field data collected from two Ecuadorian Ministry agroforestry initiatives, the *Agenda for the Productive Transformation of the Amazon* (ATPA) program and the *Project for the Reactivation of Fine Aroma National Cacao* (PRCC).

In a nutshell, there are five interrelated barriers that came up in the data that are also mentioned in the literature in some way or another. These are ideological barriers; barriers in

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[1] The key elements are: 1. Learning from success and failures 2. Available germplasm 3. Technology options 4. Farmer-centered research and extension approaches 5. Knowledge information/sharing 6. Local Institutional capacity 7. Facilitation 8. Policy Options 9. Market Options 10. Strategic Partnerships

[2] The review organizes barriers along five themes: 1)Barriers to adoption of agroforestry 2) Barriers creating inefficient markets 3) Barriers for agroforestry extension services 4) Barriers for relevant research 5) Barriers in institutional arrangements and policies.

program management; barriers for well-suited agroforestry design; barriers in agroforestry management and pedagogy; and systemic bottlenecks. Underlined are existing methods that are best suited for addressing these barriers. For the Ecuadorian case study, the following tools/frameworks are most appropriate:

Off-farm

- Structured Decision Making (SDM) processes for program design and management.
- Principle-Based Conceptual Frameworks for adaptive management
- Rapid Appraisal for Agricultural Innovation Systems (AIS) and partner engagement models

On-farm

- Participatory Agroforestry Design: Four-step guide analysis and design of shade canopy
- Tools for Gender and Social Inclusion
- Farmer Field Schools (FFS) and Climate Field Schools (CFSs)

CHAPTER 2

THE ACTION-RESEARCH PROCESS: PARTNERS AND METHODS

The Agroforestry Action Agenda in Ecuador: ATPA and PRCC

Ecuador is one of the nine countries in the Latin American and Caribbean (LAC) region that has explicitly made agroforestry a national policy priority (Suber et al., 2018). The new Ecuadorian Agricultural Policy[3] - *Toward Sustainable Rural Development 2015-2025* - articulates agroforestry as a plank for simultaneously restoring ecosystem health, increasing agricultural productivity, enhancing rural livelihoods, and mitigating climate change (Bonilla, 2016). As a result, Ecuador has redirected its thrust in the direction of agroforestry landscapes with the assistance[4] of international organizations, such as the Global Environment Facility (GEF), the Green Climate Fund (GCF) and the United Nations Development Program (UNDP). The action agenda of Ecuador and other tropical countries regard the cultivation of cacao (*Theobroma cacao*[5]*)* under the shade of other trees as a model for profitable agroforestry systems (Armengot et al., 2016; Asare et al., 2014; Vaast & Somarriba, 2014b)

In 2015, the Ecuadorian Ministry of Agriculture and Livestock (MAG) launched the *Agenda for the Productive Transformation of the Amazon* (ATPA) program in the Amazonian

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[3] The Ecuadorian Agricultural Policy proposed a new agricultural model guided by the sustainable use of land, water, genetic and other natural resources used in agricultural production. Therein, agroecological systems, such as cacao-based agroforestry, were presented ecologically-sound, economic development strategies for the most marginalized areas and communities of the country.

[4] Technical and financial assistance is provided through the program called "Integrated Amazonian Program for the Conservation of Forests and Sustainable Production" (PROAmazonía).

[5] A tropical understory tree native to the Amazon and Central America. Its seeds (.i.e. cacao beans) are extracted from large, colorful pods growing on the tree, fermented and dried to make the raw material of the world's chocolate (Young, 2007).

region. The main goal of ATPA is to scale-up agroforestry as an economically viable strategy to hold the Amazon rainforest boundary and restore soils mainly lost to pasture[6]. The portfolio of agroecological productive alternatives includes shade-grown cacao and coffee, silvopasture, and other multi-strata[7] homegardens and agroecological[8] designs. At a basic level, ATPA's theory of change is that by assisting self-selected farmers and producers' associations in the establishment of tree-based polyculture systems (.i.e. different forms of agroforestry) and marketing channels, agriculture systems will transition away from extensive livestock systems and the monoculture cultivation of cacao, coffee, dragon fruit, oil palm, sugarcane and other crops (MAG, 2017). To this end, public extension agents provide technical assistance, market development and in-kind support[9] to indigenous Shuar and mestizo (male and female) farmers.

ATPA is an analytically useful case study for the following reasons:

- First, ATPA is a pioneer project in the region because it integrates conservation-oriented perspectives with poverty alleviation goals by employing a landscape-level approach. The program has compiled GIS data to identify key areas of deforestation in the Amazonian provinces, buffer zones, and land uses, so that it can spatially target and prioritize areas where agroforests are most needed. Landscape approaches to natural resource management

[6] A strikingly high 82% of the agricultural area in Morona Santiago is used for pasture, making cattle ranching the main driver of deforestation in the country

[7] These may include citrus trees, timber and Amazonian native species, such as borojó, ungurahua and cinnamon.

[8] For example, plantations of dragon fruit require high amounts of light, making it hard to integrate into a highly diversified agroforestry system. A live fence of *Trichantera gigantea* – a medicinal, firewood and fodder tree - will then be placed around the perimeter of the plot and pollarded routinely to increase light availability.

[9] Market development is done primarily by establishing farmers' markets, while the in-kind support may include tools, grafted trees or timber species for an experimental plot (1ha.)

call for similar forms of coherent spatial planning to identify synergies and trade-offs between various sectors and land uses involved (Denier et al., 2015).

- Second, ATPA aims to expand marketing opportunities for under-utilized Amazonian crops -such as ungurahua, borojo, and amazonian cinnamon- at local, regional and global scales. Polycentric food distribution networks like these are thought to be essential for fostering resilience at all levels of the food system, from production, to distribution, to consumption (Schipanski et al., 2016).
- ATPA shares some theoretical foundations with Farmer-first/Participatory/Endogenous perspectives[10] of rural development, in that it aims to incorporate farmers‘ technical knowledge and needs into land use planning. This is in line with the idea that Rural People‘s Knowledge (RPK) captures crucial ecological and agronomic information, and that harnessing farmers‘ decision-making power makes for effective and inclusive development practice (Scoones et al. 2009).
- ATPA has designed a multi-step, decision-aiding tool –the Integrated Management Plan (IPM, for its name in Spanish)- for helping technicians provide more technically informed and more participatory recommendations to farmers. The procedures involved in IPM include the collection of GIS data, land use mapping[11], financial and livelihood systems information[12], and agronomic surveys as part of the process of proposing land use change. In this respect, IPM resembles Farming Systems Research-Extension procedures because

[10] Farmer-First/Participatory/Endogenous traditions emphasize that agricultural development comes from harnessing local resources and knowledge. (Chambers and Jiggins 1987; Pigford et al. 2018; (Bosworth et al. 2016)
[11] Mapping is a common participatory technique. In this case, the goal of IPM is to have farmers map out all of current land uses, including farms, infrastructure, and natural resources, such as bodies of water or forests. Then, the goal is to draw any future changes with the input of extension agents.
[12] This includes socio-economic information, such as family labor, off-farm jobs, market connections, education level, etc.

it seeks to conduct a systems-level diagnosis and action plan with the input of farmers (Collinson, 1987).

Like most government extension programs, ATPA overlaps and works in conjunction with other government programs .i.e. the *Project for the Reactivation of Fine Aroma National Cacao and Coffee* (PRCC) - an agroforestry initiative that began working in the Ecuadorian Amazon in 2011. ATPA and PRCC technicians in the field are in constant communication, share office spaces and vehicles, target the same population, and often perform each others' job duties when faced with personnel shortages or deadlines. In many cases, ATPA staff is permanently or temporarily transferred to PRCC, and vice versa. To account for this operational reality, PRCC staff and beneficiaries were asked to participate in interviews and farm visits along with their ATPA counterparts.

Research practice with a social change agenda: design and methods

The purpose of the rapid appraisal was twofold. The first goal was to synthesize the literature and use the case study results to understand how agroforestry benefits are difficult to scale-up. The second, action-oriented goal was to lay out a series of methods and frameworks for overcoming these obstacles, which other development practitioners working in rural tropical landscapes might find useful.

How this rapid appraisal came to be is as important as what came out of it. In line with action-research principles, the rapid appraisal was the result of a collaborative process in which the problem statement and scope of research were defined with program staff in the Ministry of

Agriculture and Livestock (MAG). Though the *levels* of participation[13] in the research process differed significantly for management staff, field staff and farmers, we aimed for the cogeneration of knowledge to the extent that was possible given financial and time constraints.

The methods .i.e. a desk-based and field-based tools employed over a period of 10 months, were designed by the lead researcher and approved by MAG. All of this followed a preliminary, exploratory trip to nine counties and fourteen rural communities where ATPA and PRCC had been working for at least 2 years. Almost half a year later, data was formally collected during a three month period of field work. During that time, the scope and methods of research underwent changes to adapt to operational realities on the ground. One of the main limitations of this study is that I was unable to access baseline information, progress and evaluation reports for ATPA and PRCC. This means that the analysis below might overlook important information, including accomplishments, for both of these programs.

Four counties (Tiwintza, Taisha, Mendez, and Sucua) were selected with the help of ATPA staff to maximize number of cacao agroforestry initiatives, eco-zones, number of both Shuar and mestizo households, number of years of Ministry involvement in the region, and number of both remote and central rural villages.

Information was collected from the study subjects listed below:

- A snowball sample of 42 Shuar and mestizo, female and male, cacao producers. Of this group, 70% live in 'difficult access' sites .i.e. communities with river access or with

[13] Based on a typology of participation, farmers' level of participation was merely "consultative," meaning that they "[were asked their] opinions without guarantee of influencing decisions." (Bommarco et al., 2013; Waldron et al., 2017)

limited public transport and no road access. Of the 42 study subjects, at least 21 belonged to farmer groups. The sample was disaggregated by gender, ethnicity, and road access (a proxy for access to markets, inputs and information).

- Of this same group, approximately 88% of the parcels visited had an Integrated Management Plan and 100% had received, in the last year, technical assistance from MAG. Farmers had either trialed or adopted one or more agroforestry technique in the past 3 years.
- Semi-structured interviews were conducted with 11 male and 3 female agroforestry technicians who provide agricultural technical assistance to ATPA and PRCC project beneficiaries in the Tiwintza, Taisha, Sucua and Mendez counties.
- Other key informants included representatives of the National Institute of Agricultural Research (INIAP), provincial and municipal government officials (GADs), the Interprovincial Federation of Shuar-FISCH Centers, the Ministry of Industries and Productivity, and the "Integrated Amazonian Program for the Conservation of Forests and Sustainable Production" (PROAmazonia).

The methodological style was relational at its core – there was a lot of back and forth across parties. Off the field, a number of academic publications, professional reports, and official extension materials from ATPA/PRCC and various institutions around the world were synthesized in preparation. On the ground, the two main data collection instruments were Farm Transect Walks and Semi-structured Interviews, with some structured observation of meetings and roundtables. (See Appendix I for data collection instruments). The data generated from these methods comprise the data base upon which the analysis in this paper is constructed.

Farm walks with the interviewees collected information on canopy structure, cacao genotypes, annual and perennial crops, spatial arrangement, management and innovation, propagation of cacao cultivation, and farmers innovations. The interviews were semi-structured, confidential and voluntary, with a duration of approximately 30 minutes. Conducted in Spanish, the questions included a breadth of socio-economic, climatic, cultural and biophysical themes.

A thematic analysis of the data gathered during farm walks and interviews was done within two months of returning to Ithaca, New York. Recurrent themes in interviews and information from Farm Transect walks were divided in nine categories: characteristics of the cropping system; extension delivery; program management; research institutions and procedures; economic and commercial concerns; climate change; behavior change and innovation; gender and social inclusion. The barriers discussed in this paper are the result of a subsequent analysis of how these themes were interconnected.

Finally, it should be noted that the recommendations presented here are, to an extent, a synthesis of insights articulated by field staff and farmers themselves during interviews and farm visits. Stakeholders themselves are aware of what blocks the success of their work but they seldom have the chance to articulate their thoughts and systematize them. Thus, the way this rapid appraisal came to be embodies a key conclusion of this paper. That is, spaces of reflection, joint and iterative learning are key to transitioning to more sustainable systems.

CHAPTER 3

NOT ALL AGROFORESTRY IS EQUAL: CACAO PRODUCTION SYSTEMS IN ECUADOR

Agroforestry Discourses

Agroforestry is as much a cropping system and indigenous art as it is a paradigm and a discourse. Agroforestry systems (AFS) have gained popular currency as a solution for nearly everything, everywhere. And for those of us who lack the embodied knowledge of what being a small agroforestry farmer actually entails, it is especially tempting to claim AFS as a silver bullet. The predisposition to mentally construct panaceas is one of the reasons why examining farmers' perceptions is important – to test our preconceptions and opinions against the realities of those who have more skin in the game. Surely one of the most intriguing realizations of this study was that neither farmers nor front-line extensionists agree on the definition, desirability and feasibility of agroforestry systems (and other related concepts[14]) (Burgoa 2019). Indeed, there is often a gap between agroforestry aspirations and agroforestry realities that has remained unquestioned (Burgoa 2019; German et al., 2006b). It is in this gap – this illusory understanding of a monolithic and all-benign agroforestry – that we find the first barrier to scaling-up AFS. Discourses that oversimply and romanticize agroforestry get in the way of engaging in critical discussion about what AFS are – or should be –and about the ground-level dilemmas farmers might face (Burgoa 2019; German et al., 2006b).

This chapter presents findings on the typology of cacao production systems in Ecuador as a way to challenge the implicit and explicit presumption that AFS on the ground are automatically ecologically-sound, user-friendly and economically advantageous. The typology brings into the

[14] Concepts of 'landscapes' and 'climate-smart agriculture' remain nebulous.

limelight not only the subtleties that exist in the umbrella term "agroforestry" but also the relative benefits/disadvantages provided by different agroforestry production models.

The findings further show that while a range of agroforestry types are possible, there is a growing appetite among small-scale, Amazonian farmers to 1) reduce tree cover in cacao production, independent of cultivar(s) preference; 2) remove permanent shade; 3) and either increase CCN-51 cropping area or fully replace 'Nacional' varieties with CCN-51 (Burgoa 2019). This goes against ATPA and PRCC expectations that farmers would want to diversify their farms, and that shade-grown cacao with 'Nacional' varieties would be well-received by beneficiaries. Though unfortunate, understanding the trends and complexity of agroforestry practice does not override the well-demonstrated potential of AFS to simultaneously address multifaceted needs. If anything, it helps us understand farmers' decisions and move away from ideological approaches to agroforestry implementation, so that development practice can move forward.

Agroforestry on the ground

Generally defined, agroforestry is an umbrella term for various land use technologies that deliberately integrate woody perennials (trees or shrubs) with annual crops and/or animals. This can include a subset of regimes/enterprises and a range of practices, such as agrisilviculture (crops and trees) silvopasture (animals and trees) and agrosilvopasture (crops, trees, and animals); as well as bee-keeping with trees, fish farming with trees, mushroom or ginseng cultivation under canopies, and even urban food forests[15] (P. Nair, 1993; Sinclair, 1999). These enterprises encompass a universe of agricultural practices, such as growing high densities of forage plants for animal fodder in silvopasture systems; or planting West Indian Pea as field borders and windbreaks (Fernandes & Nair, 1986; Gabriel, 2018). Whatever the arrangement, all

[15] The intentional use of perennial food-producing plants in parks, underutilized land or residential gardens in cities (Lovell, 2010).

agroforestry systems (AFS) are -at a basic level- *polycultures* where *woody perennials* are a key component of the management regime. But no agroforestry is equal in that different systems will provide different services.

In reality, farmers manage one or many agroforestry enterprises and do so in different ways (Sinclair, 1999). They might be very "hands-off", or they might employ organic or synthetic inputs; they might want to sell most of their harvest, or consume the harvest at home; they might want as many trees as possible, or only few here and there. *The bottom line is that these differences determine the productivity, profitability, and ecosystems services provided by a given agroforestry enterprise.* Cacao agroforestry types illustrate this point.

Not all Cacao is Equal: Typologies

Cacao (*Theobroma cacao)* is a tropical understory tree native to the Amazon and Central America, its seeds (.i.e. cacao beans) are extracted from large, colorful pods growing on the tree, fermented and dried to make the raw material of the world's chocolate (Young, 2007). Shade-grown cacao is one of the most well-researched cropping systems and is often a poster child of sustainable agroforestry along with shade-grown coffee .

Produced in seven agro-ecological zones in both the Coastal and Amazonian regions of Ecuador, cacao is a key commodity crop, with over 80% of the production destined for export and the rest sourced by national artisanal chocolatiers (Ahmed & Arrisueno, 2015; Amador, 2011). In both volume and quality, Ecuador is a major player in the global cacao industry: it is the second largest producer of "bulk or conventional" cacao in the western hemisphere, as well as the main producer of the top quality, "fine flavor cacao" (also known as 'Cacao Nacional') in the world (FAOSTAT, 2019; Jano & Mainville, 2007; Quiroz, 2016; Winkel, 2013). Thus,

ensuring optimal cacao yields is a high national priority for the government and a commercial objective for many small and medium farmers in the country.

Cacao production in Ecuador varies greatly in structural and functional complexity[16]; techno-managerial aspects[17], cultivars[18] and commercialization opportunities[19]. Farming methods range from technified plantations of clones[20] grown under full sun, to a range of varieties grown under permanent shade. Based on primary data collected in the area of study, there are five broad shade canopy typologies[21] in Morona Santiago, Ecuador (See Appendix II for a visual representation).

Low-Medium structural complexity types

(1) Cacao with only temporary shade/ full-sun cacao: cacao with provisional overstory shade removed after a 1-2.5 year period of establishment (e.g. cacao-*Musa spp.*,cacao-corn, cacao-cassava). Understory staple crops, such as *Colocasia Esculenta* and ginger, may be present as a result of natural regeneration or intentional planting.

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[16] Complexity is a function of the spatial arrangement, temporal arrangement and species selection.
[17] Differences can be found in relation to application of inputs (organic vs. synthetic), irrigation, shade management practices, pest management practices, agronomic management of other perennial and/or annual components.
[18] A broad range of the Cacao Nacional types were most common, followed by CCN-51 and Super Arbol.
[19] Commercialization is easier in Coastal regions. Commercialization is hardest in communities with boat-access, hike-access, no phone service, and no producers' groups. Commercialization of dried beans is primarily done through intermediaries, very few of which pay the price premiums for (high-quality) Cacao Nacional varieties.
[20] A clone is an asexually propagated variety selected for desirable characteristics. The most common clones found in the visited farms were EET-95, EET-96, EET-103, CCN-51 and Super Arbol. In some cases, farmers were selecting and grafting germplasm from their own farms.
[21] The typology here departs significantly from the one found in the literature (De Melo Virginio Filho et al., 2014; Lindgärde et al., 2004; Rice & Greenberg, 2000; Somarriba, 2004, p. 20; Torres et al., 2015).

(2) Cacao with permanent lateral shade: cacao with no overstory shade but with planted or re-grown field borders[22] of timber, fruit, or fertilizer perennial or annual species (e.g. *Musa spp*, sugarcane, jackfruit, *Bactris gasipaes, Inga spp.*, citrus).

(3) Cacao with permanent, fertilizer shade canopies: cacao with overstory shade of a few *Inga spp.* legume trees, interplanted or clustered.

Medium-High structural complexity types

(4) Cacao with permanent, productive shade canopies: overstory shade of one or few fruit, timber or palm species for income and/or house consumption; most commonly, *Musa spp.*, *Cordia Alliodora*, and *Bactris Gasipaes*[23].

(5) Cacao with mixed (productive and fertilizer) shade: cacao grown under mixed shade canopy. Tree cover is composed of haphazardly arranged species that have either naturally regenerated, or that have been retained from the original native forest or intentionally planted. As many of 31 perennial and seven annual species were identified (See Appendix II for a list).

Trade-offs at the farm and landscape level

All of these types classify as 'cacao agroforestry' but yield different outcomes as a result of their species composition, spatial and temporal arrangements. Types (4) and (5), on the higher end of the tree cover gradient, are generally what people have in mind when they think of 'multifunctional agroforestry' or 'multi-strata agroforestry.' At the landscape and global level,

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[22] Field borders cast different shade levels depending on tree height, density and canopy structure; and movement of the sun relative to the plot.

[23] Peach Palm (*Bactris Gasipaes)* is most prevalent in Shuar communities. It is valued not only for its fruit and heart of palm, but also for the edible larvae that grow in the stem, known as "mukindi."

type (4) and (5) maximize the positive externalities[24] of agroforestry, including clean water and air, flood mitigation, carbon sequestration and biodiversity conservation (Jose, 2009). With higher intra- and inter-species richness, these types retain higher functional diversity and redundancy (an indicator of resilience), thereby enhancing the productivity[25] of cacao and other crops. Also as a result of their composition, (4) and (5) can deliver a range of provisioning services (e.g. commercial, food and food preparation, fiber, dyes, tools, construction, fodder, fuel); regulatory services (e.g. shade, fertilizer); and cultural services (e.g. medicinal, ornamental, ritual, handicrafts, veterinary) (Burgoa 2019; Bennett et al. 2002; Caballero-Serrano et al. 2016). The ability to satisfy a range of livelihood needs on different time horizons is what makes these systems an appropriate risk-management strategy to deal with fluctuating market prices, pest outbreaks, and climate variability (Torres et al. 2015).

Lower shade levels, however, have a number of economic, productive and operational advantages over more complex types. First, type (1) and (2) are generally more profitable in the short-term, producing higher crop yields[26]and reducing the incidence of fungal diseases[27]. Second, simpler systems generally have higher densities of a single crop and can therefore

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[24] A comparison of 229 cacao-based agroforestry systems in Central America found that cacao plantations with specialized shade store higher amounts of carbon below- and above-ground than other types of shade-grown systems and monocultures (Albrecht and Kandji 2003; Somarriba, Cerda, et al. 2013; Abou Rajab et al. 2016). Furthermore, cacao agroforests along the typology have been used as corridors for forest connectivity, particularly on zones with high-conservation values and high rates of tropical deforestation (Asare et al. 2014). Jose (2009) summarizes the ecosystem services generally associated with agroforestry at different spatial scales.

[25] Enhanced productivity is ultimately a function of design and management. Nonetheless, compared to systems with reduced tree cover, (4) and (5) types exhibit higher soil organic matter. Fewer nutrient losses to leaching and erosion, enhanced pollination success, weed and biological pest control are thought to sustain and even improve yields in the long-term (Buresh et al. 1996; Pinho et al. 2012; De Beenhouwer et al. 2013; Lasco et al. 2014; Abou Rajab et al. 2016).

[26]Higher photosynthetic activity increases crop yield potential, assuming the necessary nutrients are presents. Crop yields are also inversely related to shade levels because fewer shade trees implies higher cropping densities of cacao.

[27] Higher shade levels create favorable conditions for fungal diseases - Witches Broom, Black Pod, and Frosty Pod – to proliferate.

accrue more crop volume, which satisfies market needs of cacao value chains and decreases transaction costs (Mukarutagwenda, 2018). Third, compared to more diversified farms, type (1) and (2) are desirable from a techno-managerial perspective because heterogenous tree cover substantially complicates management regime. As Somarriba (2018) explains, ”imagine the complexity of selecting pruning frequency and intensity for 30+ tree species in a shade canopy, each with different crown architecture, canopy growth rate, tolerance to pollarding and so on!” (p.13). It is, therefore, crucial to the scaling-up conversation, that we acknowledge the on-farm disadvantages of cacao systems on the higher end of the shade gradient.

Those concerned with high biodiversity losses under full-sun systems have called for policy action to reverse the trend towards the open sun cultivation (Díaz-Montenegro et al., 2018; Franzen & Borgerhoff Mulder, 2007; Somarriba, Lopez-Sampson, et al., 2018). Indeed, the market-based efficiency and operational advantages of farms with reduced tree cover have propelled the intensification of cacao production at the cost of ecosystem health, worldwide (Franzen and Borgerhoff -Mulder 2007; Díaz-Montenegro et al. 2018; Somarriba et al. 2018). In this way, open sun cultivation is not ‘climate-smart agriculture’, as it contributes to the current climate crisis and reduces adaptive capacity. A different agroforestry type would be needed to maximize the climate change mitigation co-benefits (e.g. carbon sequestration, water cycle regulation) of tree cultivation – and ensure cacao production is ‘climate-smart.’ Again, not all agroforestry is equal.

The legacies of the ‘The CCN-51 Revolution’

Trade-offs *within agroforestry types* -between crop intensification and resilience- are best exemplified by the so-called Ecuadorian ‘CCN-51 Revolution.’ In the 1960s, the development of

superior germplasm reinvigorated the Ecuadorian cacao industry after a long depressed period[28] (Amador, 2011). At the time of its release, CCN-51 (a low-quality but productive hybrid) was the first to address a number of limiting factors in cacao production, including susceptibility to diseases and low production levels. What makes this event a 'Revolution,' however, is that it propelled a shift in farming methods – from complex multi-strata systems to temporary shade/open-sun arrangements.

To a large extent, this shift in land use practices was a function of the agronomic characteristics of CCN-51. With high rates of self-compatibility,[29] CCN-51 can be high-yielding (over 3.0 Ton/ha) and highly precocious (< 2 yrs. to bear fruit) (Amador 2011; Branco et al. 2018). When compared to 10 other 'Nacional' varieties, it consistently exhibits the lowest incidence of both Witches Brooms and Frosty Pod Rot – the most destructive fungal cacao diseases in the area (Andía, 1997; Pérez Garcia & Freile Almeida, 2017). Furthermore, the clone produces large pods[30] and large seeds[31] with high butter content (54%) – all marketable characteristics in high-volume, low-grade value chains today (ATPA, 2016; Boza et al., 2014; Jano & Mainville, 2007; Kozicka, 2018).

Because CCN-51 is self-compatible and does not rely on midges for cross-pollination, it is possible to have extensive plantings of a single genotype through clonal propagation (Branco et al., 2018). Second, CCN-51 is able to withstand higher levels of sun exposure (820-2300 sun hours) after the second or third year of establishment, allowing for full-sun cultivation after a

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[28] Almost 70% of cacao farms in Ecuador had been lost to Moniliophtora roreri, a fungal disease discovered in Ecuador in 1915 (Amador, 2011).
[29] Self-compatibility is directly associated with higher yields and because it facilitates management by reducing the genetic variability of the farm (Branco et al., 2018). Most cacao plants are self-incompatible (Branco et al., 2018).
[30] 8 pods for a pound of dried beans
[31] 1.4 – 1.5 gr

period of temporary shade (Andía, 1997). Thus, profitable, short-cycled species (e.g. banana, corn) are planted to provide shade for young cacao seedlings susceptible to desiccation (Andía, 1997; Beer et al., 1998; Sánchez et al., 2017). Complete shade removal after this initial period reduces the incidence of fungal diseases that drive in humid conditions and allows farmers to increase the density of cacao trees from 1111 plants to 3000/ha (Andía, 1997; Winkel, 2013).

But the higher yields and efficiencies associated with shade removal are not necessarily positive. Studies on stress responses in different non-shaded and shaded systems indicate that full-sun conditions shorten the productive lifetime of cacao to 15-20 years, increase weed and pest pressure (e.g. mirids), and require more water and nutrients inputs (Abou Rajab et al., 2016; Armengot et al., 2016; Carr & Lockwood, 2011; Jaimez et al., 2010). In the long run, that is, *filtered* sunlight *through all life stages* is thought to be agronomically desirable[32], especially in hot and dry climates and in poor soil conditions (Somarriba et al. 2013).

Another downside to the removal of shade is that higher returns are dependent on higher inputs. Yields are often maintained through the use of Triple 15-15-15 fertilizers (600 grs/tree/year), gravity or drip irrigation systems (100mm/month) , and agrochemicals[33] (e.g. glyphosate, paraquat, malathion, diazinon) (Andía, 1997; Jaimez et al., 2010; Rice & Greenberg, 2000; Sánchez et al., 2017). Moving cacao out of shade and into dense monocultures, increases the use of synthetic inputs and puts more money in farmers' pockets *in the short-term* (Armengot et al., 2016; Beer et al., 1998; Steffan-Dewenter et al., 2007; Vaast & Somarriba, 2014b).

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[32] Although no studies were found that specify the luminosity requirements for CCN-51, it is generally understood that photon flux densities (PFD) above 400-600 µmol m-2 s-1 result in rapid leaf turnover and physical stress in *Theobroma cacao* (Abou Rajab et al., 2016; Jaimez et al., 2010).

Few studies have analyzed the production and profitability of high-density, CCN-51 plantations vis a vis. complex agroforestry farm in hectare equivalent units. One of these studies by Blare and Useche (2013) found that even when family labor is valued at the market rate, CN agroforestry systems have higher production costs and lower average revenues that CCN-51 monoculture. The economic advantage[34] of CCN-51 systems with temporary shade was consistent even when accounting for differences in standard and specialty markets (Blare and Useche 2013). The difference in expected returns between the two production alternatives indicates that there is a high opportunity cost involved in growing CN varieties under shade.

CCN-51 today

Twenty years after its release in the 1960s, the CCN-51 cultivar accounted for 90% of new plantings (50000 ha.) (Amador, 2011). And by 2015, over 60% of Ecuador's cacao had transitioned into full sun conditions, particularly in the coastal region of Ecuador where access to CCN-51 germplasm, inputs, extension and credit services were more readily available to growers (Amador, 2011; L. Trujillo, personal communication, January 1, 2020). Massive increases (73.8%) in net production occurred in only 6 years – a result of the increase in international prices, national breeding programs, and the immediate economic benefits that the cultivar provided farmers (Boza et al., 2014; Eric Boa et al., 2000).

[34] The costs for growing CN are US$564.61 per hectare/year with profits of US$608.65 per hectare/year; compared to lower production costs of US$304.40 and higher profits of US$1,223.84 for CCN-51 (Blare & Useche, 2013)

Today, CCN-51 accounts for 30% of national production but is not nearly as widespread as it once was (Burgoa 2019). In the last decade, national policies[35] have disincentivized the cultivation of CCN-51, instead prioritizing the development and extension of higher-grade yet productive 'Nacional' clones.[36] But even as ATPA and PRCC direct their efforts away from CCN-51 production, the legacies of this historical process are evident today and provide the context for understanding cacao cultivation in the study area. Indeed, through this Rapid Appraisal decision-makers learned that there is a growing appetite among small-scale, Amazonian farmers to 1) reduce tree cover in cacao production, independent of cultivar(s) preference; 2) remove permanent shade; 3) and either increase CCN-51 cropping area or fully replace 'Nacional' varieties with CCN-51 (Burgoa 2019). These findings go against projects' expectations but provide a learning opportunity to reflect on development practice.

The Ideological Barrier

Wishful thinking and misunderstandings about the nature and complexity of cacao agroforestry practice get in the way of understanding why farmers do what they do, and of why scaling-up agroforestry is not as straightforward as expected. The process of gathering feedback and systematizing farmers' (and other actors') experiences is a simple way in which agroforestry

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[35] In accordance with The National Cacao Plan, ATPA and PRCC exclusively promote 'Nacional' clones. The National Cacao Plan aims to increase the production and export of specialty cacao (not CCN-51), known as "fine or flavor," "Arriba," or CN, in order to accrue price premiums of 20-30% at the international level .

[36] The National Agricultural Research Institute (INIAP) has developed other national varieties with superior organoleptic qualities with the goal of attracting specialty chocolate markets. Known as high-grade 'Cacao Nacional' (CN), 'fine or flavor,' or 'Arriba' cacao, these materials (e.g. EET-103, EET-95, EET-96, EET-800, EET-801) are made available through ATPA and PRCC extension services.

ambitions can remain grounded in reality. This form of reflexive and participatory program design and management is a recurrent theme throughout this paper.

So, what is agroforestry? This chapter shows that 'cacao agroforestry' is yet another hypernym for a number of subsystems with distinct sets of trade-offs. Embedded in larger historical processes, like the 'CCN-51 Revolution,' these subsystems fulfill competing objectives to different extents. All in all, we can assert that the exact 'sweet spot' at which ecological and production goals is simultaneous satisfied in cacao agroforestry is a matter of continuous debate. (Coe et al., 2014; Somarriba, Lopez-Sampson, et al., 2018). What is more, the variability in farmers' site conditions, preferences and limitations might deem this an unanswerable question. Regardless of the country and the agroforestry system in hand[37], the inconvenient truth is that it is not always clear which agroforestry subsystem best satisfies multiple objectives at once – indeed, practitioners are often in need of baseline definitions, "conceptual models and tools [for optimizing multi-objective shade canopies]" (Somarriba, Lopez-Sampson, et al., 2018, p. 4). In the following chapters, I discuss how this challenge shows up in ATPA and PRCC development practice; how program leadership has attempted to navigate the uncertainty and complexity; and how they could do better.

[37] Other forms of agroforestry, too, can be typologized according to tree cover gradients and evaluated for how well they meet certain goals. (Silvopasture, for example, will yield different economic, productive, and ecological benefits depending on how many trees are found in pasture and how these are managed).

CHAPTER 4

UNRESOLVED QUESTIONS IN AGROFORESTRY: ADAPTIVE MANAGEMENT

Cacao agroforestry models are 'multi-functional' *to varying degrees* due to differences in functional and structural complexity, cultural features, management regime, germplasm makeup and commercialization potential. A positive aspect of these differences is that cacao agroforestry can match the diversity of farmers' aspirations, needs, and preferences, though (as illustrated below) it may complicate project design and implementation. Instead of romanticizing agroforestry as a monolith, programs (and donors) must acknowledge that *the plasticity of agroforestry is both an advantage and a liability* (Haggar et al., 2001). For high-level practitioners and funders seeking to support 'multi-functional' or agroforestry, the take-away of this chapter is that scaling-up agroforestry cannot do without Adaptive Management, or "an intentional approach to making decisions and adjustments in response to new information and changes in context" (USAID 2018). This goes hand in hand with the argument that gathering feedback and systematizing farmers' experience is crucial to grounding agroforestry ambitions on reality. Though popular amongst natural resource management practitioners, Adaptive Management has yet to fully infiltrate the programmatic style of agricultural government programs such as ATPA and PRCC.

This chapter showcases the extent to which ATPA and PRCC struggle with developing conceptual and operational cohesiveness in the face of uncertainty. It argues that adaptive management approaches, such as Principle-Based conceptual frameworks and Structured

Decision-Making processes (SDM) can be particularly helpful in developing baseline definitions, operational principles and strategies for scaling-up agroforestry.

Your Agroforestry is Not My Agroforestry: Debates on concepts, shade and trade-offs

The methods employed in this study allowed for a comparative analysis of the agroforestry operations and concepts of ATPA and PRCC staff. It was evidenced in this process that conceptual and operational discrepancies exist *between* and *within* ATPA and PRCC management and field staff that hinder the scaling-up of agroforestry benefits.

Field technicians and management staff (in both programs) were inconsistent – and sometimes contradictory – in their understanding of what "counts" as cacao agroforestry. A third of the participants exclusively defined cacao agroforestry as a diversified system (.i.e. at least two, integrated tree crops) where cacao grows under a *permanent* overstory canopy; others, implicitly or explicitly expanded the definition to include systems with *lateral* and/or *temporary* shade (.i.e. full-sun cultivation with or without understory crops). As a result, some farmers (in similar site and socioeconomic conditions, and with similar objectives) received contradictory technical backstopping on how much shade is or is not appropriate. In extreme cases, this resulted in technicians advising farmers to establish cacao (and coffee) monocultures, arguing that this also classifies as agroforestry (Burgoa 2019). More frequently, this manifested in the establishment of the full-sun, temporary shade cacao models, which are beneficial in that they increase short-term income and facilitate farm operations but are undesirable in that they promote homogenization of the farm and landscape in the long-run. Farm visits and farmer interviews corroborated these operational discrepancies. Though no data was formally collected

for other forms of agroforestry, it should be mentioned that – in conversation and in farm visits - such discrepancies were also palpable with regards to silvopasture systems.

Operational and conceptual discrepancies were coupled with varying opinions on the feasibility, benefits and trade-offs of the spectrum of cacao agroforestry types that would ensure ecological benefits and optimal cacao yields of , specifically, 'Cacao Nacional' (CN) genotypes. While some personnel asserted that permanent, mixed overstory shade is ecologically sound *and* essential for CN cacao to express its utmost productive potential, others found that complex shaded arrangements were climatically[38] and economically[39] unviable for farmers, regardless of the cultivar used. Even when participants agreed that "some" shade was desirable, shade levels were unspecified and there was no consensus on how to best diagnose, design and manage the tree canopy to ensure cacao productivity. In such cases, the general rule was that cacao agroforestry farms must not be "overpopulated," primarily due to the high incidence of fungal diseases. All in all, it was evidenced that - where cacao production is a key objective – "shade" is a contested topic (Burgoa 2019).

Scale and Uncertainty

Less evident but of equal importance were incongruities related to the spatial *scale* (e.g. plot; farming system; landscape) at which agroforestry benefits were expected to be realized. The notion of a 'landscape approach' was mentioned amongst some high-level staff members in ATPA (not PRCC); yet it was unclear how a 'landscape approach' actually guided the technical

[38] Farmers and extensionists expressed that implementing overstory shade was realistic in the dry coastal areas but counterproductive in the humid Amazonian conditions.
[39] Losses due to fungal diseases in complex agroforestry, together with low prices, increased the opportunity-cost of complex agroforestry. Both farmers and extensionists highlighted the lack of a commercial strategy to address this challenge (Chapter 6).

backstopping provided by field technicians. *"What does it mean to work at a landscape-level, anyway?"* asked a participant, epitomizing the overall confusion about what was meant by the term (Burgoa 2019). This was surprising given the dedicated efforts of ATPA to create an Integrated Management Tool to map out farming system and spatially target areas with high deforestation rates. In practice, the quantity of multi-sectoral information that needs be analyzed after the long process of data collection is not only operationally costly but also analytically difficult. Thus, ATPA is often faced with the perennial problem of data-overload and analytic paralysis (Chambers & Jiggins, 1987; van Ittersum et al., 2008).

The need for a 'landscape approach' with clearer definitions, boundaries, and operational tools has been recognized and tackled[40] by global development practitioners around the world, though few[41] have written about *agroforestry landscapes* per se. When it comes to agroforestry types, questions of scale are crucial in judging the tree cover gradient that best supports a set of outcomes. For example, if the question of agroforestry complexity is tackled at a larger spatial scale (e.g. farming systems, landscape-level), then "simpler" (e.g. lateral shade) agroforestry farms that are easier to design, manage and even commercialize may increase the multi-functionality of a landscape. If the main goal is, rather, to increase functional redundancy and maximize tree cover *at the farm or plot level*, then multi-strata arrangements are more fitting. Either way, at a conceptual and operational level, spatial scale influences how we expect agroforestry to balance ecological, productive and livelihood trade-offs.

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[40] These issues are tackled in depth in the Little Sustainable Landscapes Book by Global Canopy Programme (GCP), EcoAgriculture Partners, the Sustainable Trade Initiative (IDH), The Nature Conservancy (TNC), and the World Wide Fund for Nature (WWF).

[41] A compilation of authors that have written about a landscape approach to scaling-up climate-smart innovations can be found in the book *Climate Smart Landscapes* by Minang et al. (2018)

One of the main reasons why landscape approaches have gained currency in recent years is that climate change adaptation and mitigation requires actions at scales larger than the field or farm (Minang et al., 2018). Thus, the conversation has switched from 'climate-smart agriculture' to 'climate-smart landscapes'[42] (Scherr et al., 2012). For ATPA and PRCC field staff, however, the threat of climate change is as real as it nebulous. For example, field staff responses[43] to the question - *"how does climate change influence cacao phenology, cacao agroforestry implementation and management in the Ecuadorian Amazon?"*- highlighted widespread uncertainty regarding the expected impacts of climate change at a local scale and for specific crops (Burgoa 2019). To an extent, this knowledge gap reflects a lack of scientific communication between research institutions and extension mechanisms. It also speaks to a general absence of reliable climate models that make predictions at geographic scales and timescales (e.g. timing of rains, intra-seasonal rainfall patterns) that are relevant for farmers and farming activities (see Chapter 5.) (IIED, 2009; Martínez-Cruz et al., 2017). Globally, predictions, risk reduction and adaptation are difficult because of the uncertainty of future climate policies, greenhouse gas emissions, social and ecological feedback loops, and unknown tipping points. In this way, climate change development adds a layer of complexity and uncertainty to agroforestry practice.

Ways forward: Adaptive Management of Agroforestry Landscapes

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[42] Scherr et al. (2012) identified three key features of climate-smart landscapes: "climate-smart practices at the field and farm scale; diversity of land use across the landscape to provide resilience; and management of land use interactions at landscape scale to achieve social, economic and ecological impacts."(p.1)

[43] All but three respondents said they were unaware of the specific effects of climate change on cacao agroforestry in Morona Santiago and/or unsure about how to include climate change information in farmer trainings. Three respondents were more specific in that they expected an increase in competitive grasses, higher incidence of cacao fungal diseases and changes in seasonality affecting post-harvest management (e.g. fermentation and drying processes) of the cacao beans.

Even in the face of uncertainty, a level of conceptual and operational cohesiveness across institutional bodies is possible and essential to all scaling-up efforts. Agroforestry programs can benefit from following structured procedures that help the management staff make multi-variable decisions in the face of uncertainty (Gregory et al., 2001). These formal mechanisms, known as Structured-Decision Making processes (SDM)**,** have been applied to several natural resources management dilemmas and can walk practitioners through:

1) debating and setting context-specific, scale-specific definitions, principles and objectives of agroforestry and other related concepts (e.g. landscape, resilience);

2) identifying the courses of action that – statistically - are more and less likely to solve multi-objective trade-off problems;

3) learning from management outcomes and modifying subsequent behavior.

Born from risk analysis and decision theory, SDM provides axioms for *how* to make complex decisions and is generally structured along five core elements [44] (See Hammond et al. (2002) for a full explanation). When multi-criteria decisions need to be made, alternative course of actions are statistically modeled and analyzed to see how well each alternative meets a set of objectives.

Even simpler decision-support approaches (e.g. Objectives Hierarchies, Decision Trees and Consequence Tables, which can be done without *R* statistical software) might prove useful in breaking down complexity while acknowledging uncertainty. Better programming, planning and

[44] The steps are represented by the acronym ProAct: problem; objectives; alternatives; consequences; tradeoffs; decision; additional steps (Hammond et al., 2002)

management – and therein, more efficient scaling-up – should result from the *iterative*, structured analysis of agroforestry options as new information about the system is gathered.

A complementary way of adaptively managing complex systems is to develop a Principle-Based Conceptual Framework for carrying out project activities. This alternative is less precise but more intuitive and comprehensive than SDM; does not require personnel with statistical software skills; and has already proved helpful in scaling-up other agroecological methodologies in West Africa (Styger & Gaoussou, 2018). Below, I provide a long term continuum of stages in the scale-up process, originally developed by The West Africa Agriculture Productivity Program (WAAP) and significantly edited to best fit ATPA/PRCC and other agroforestry initiatives. These can be adapted to the needs of different agroforestry programs.

Stage 1: **Develop a common understanding** amongst project (field and management) staff and use consistent terminology about cacao agroforestry, landscapes, climate change mitigation and adaptation, etc.

Stage 2: **Create learning alliances**, also known as "communities of practice," to identify areas of uncertainty, formulate questions and engage in joint action. Spaces of interaction should follow the best practices[45] for partner engagement models (Chapter 6).

[45] A review of multi-stakeholder platforms, design criteria and elements of success can be found in Kaner (2007), Schut et al. (2018), Garard et al. (2018) and Aerni et al. (2015).

Stage 3: **Harmonize an implementation strategy** within and across programs and strategies for achieving the best possible short-term outcome. Implementation strategies are subject to continuous revision.

Stage 4: **Monitor, analyze, communicate and co-learn** from field results, from and with farmers. Based on continuing inputs of information, **employ a methodological bricolage** (see Chapter 4 and 5) that best fits the local conditions.

Stage 5: **Promote large-scale change** by publicizing results of data analysis and engaging in dialogue with national and regional policy-makers.

Stage 6: **Go through stages 1-6 in a cyclical manner** for achieving long-term outcomes.

This chapter has presented management approaches to which we may resort for navigating the barriers that result from:

- the gap between agroforestry ambitions and agroforestry realities;
- the potential variability in agroforestry objectives and forms;
- the scientific uncertainty regarding "sweet spots" of ecological and economic co-benefits in agroforestry practice;
- and the complexity of making decisions at larger scales and under climate change risk and socio-ecological uncertainty.

CHAPTER 5

RESEARCH AND EXTENSION APPROACHES FOR SCALING-UP AGROFORESTRY

The model of the Ecuadorian Agricultural Research and Extension System

Generally speaking, the more diverse the AFS gets, the harder it is to design and/or manage. Add to this the variability in farmers' profiles and we have a multi-variable system that follows no blueprints. A program's strategy for working with these inevitable challenges alongside farmers influences the potential performance and resilience of AFS. Hence, the need to analyze the philosophy, tools and structure of ATPA and PRCC extension services.

Most, though not all, of ATPA and PRCC activities operate under Transfer of Technology (ToT) principles[46] of agricultural research and extension. Under this model, agricultural problems and solutions are crafted a-priori from the perspective of scientists, tested in research stations lead by the National Institute of Agricultural Research (INIAP). Solutions are then handed over to front-line extensionists in the Ministry of Agriculture and Livestock for wide-scale promotion. With 7 research stations and several validation plots all over the country, INIAP has focused cacao research on developing productive and high-quality cacao varieties in full-sun, temporary or lateral shade agroforestry arrangements (Burgoa 2019; INIAP 2019).

INIAP then distributes these varieties – the EET-95, EET-96 and EET-103 – to ATPA and PRCC extensionists, who facilitate the provision of germplasm, provide consultations, and conduct on-farm demonstrations for individual farmers and farmers groups (Burgoa 2019).

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[46] Premised on the idea that the locus of innovation is in research stations led by scientists, ToT diffusion models see extensionists as the vehicle for passing down agricultural technologies to a handful of pioneer farmers, known as 'early adopters' (Chambers & Jiggins, 1987). Transfer of Technology (ToT) has remained the dominant model for agricultural extension since the 1960s.

Because these activities focus on dispensing information to farmers, ATPA and PRCC fundamentally follow a linear ToT understanding of the wide-scale adoption of agroforestry innovation.

This chapter deals with two interconnected barriers related to the process of designing agroforestry systems and then learning how to manage them. The first barrier is that the Transfer of Technology pipeline is inadequate for producing 'best-fit' agroforestry designs, as the latter requires a combination of technical backstopping and farmer participation that is not typical of ToT philosophy, tools or structure. The second barrier is that ToT does not facilitate the development of fitting agroforestry management regimes; the current educational methods employed are out of tune with farmers' learning needs and blind to gender and social inclusion and climate action.

Perspectives on Agricultural Innovation and Rural Development

Theories on agricultural rural development, and on urban-rural relations in general, have shifted dramatically over the past two decades (Black, 2000; Bock, 2016; Bosworth et al., 2016). At one end of the spectrum are exogenous models like the popular Transfer of Technology (ToT), which frame agricultural innovation as the result of a linear, 'top-down' diffusion of science-based technologies that are imported from urban to rural areas. Farmers are treated as recipients -not creators or co-creators – of innovation. ToT diffusion models see extensionists as the vehicle for passing down agricultural technologies to a handful of pioneer farmers, known as 'early adopters' (Chambers & Jiggins, 1987). This framework has remained the dominant model for agricultural extension since the 1960s (Black, 2000) and continues to frame most of work activities of ATPA and PRCC

This view stands in contrast to theoretical traditions that understand agricultural innovation as a process that is endogenous to farmers and to rural communities – 'bottom-up'

strategies can be generally classified as Farmer-First/Endogenous approaches. Grounded on the basic tenet that stakeholder involvement is crucial for equity and efficacy in development work, "participatory approaches" encompass a range of methods that call for different *levels* of participation. (Agarwal (2001) has identified six different types[47] of participation). Some approaches prioritize farmers' participation in on-farm experiments, for example, while others expect stakeholders to have more decision-making power in project design (Agarwal, 2001). Having some form of stakeholder participation has become almost mandatory in development work, but programs abide by this protocol to varying degrees.

The polarity between these two (exogenous and endogenous) perspectives has framed much of the discussion on agricultural extension since the 1960s[48] (Aerni et al., 2015; Black, 2000; Chambers & Jiggins, 1987; Collinson, 1987). Both approaches have strengths and weaknesses and may be more or less applicable depending on the circumstances. More integrated, "in-between" viewpoints- such as Agricultural Innovation Systems (AIS) – are also becoming mainstream in recent years and are the topic of Chapter 6.

Exogenous, ToT model for scaling-up agroforestry

Programs that follow the ToT model can make and have made positive contributions. National research institutes like INIAP devote significant human and financial resources to test and validate ideas, and have come up with innovations that have addressed farmers' constraints

[47] 1. Nominal participation: membership in the group 2. Passive participation: being informed of decision ex post facto; or attending meeting and listening without speaking up 3. Consultative participation: being asked an opinion in specific matters without guarantee of influencing decisions 4. Activity-specific participation: being asked to (or volunteering to) to undertake a specific activity. 5. Active participation: expressing opinions, whether or not solicited, or taking initiative of other sorts. 6. Interactive participation: having voice and influence in the group's decisions. (Agarwal, 2001)

[48] Scoones et al. 2009 present a detailed comparison of these perspectives in their book *Farmer First Revisited.*

in the past. The CCN-51 Revolution described in Chapter 3. is a clear example of how expert-led innovation in research stations *can* respond to the needs of at least a subset of farmers. Moreover, the Transfer of Technology pipeline plays an important role in providing technical backstopping and minimizing the risk associated with agricultural experimentation – a risk that many resource-poor farmers may not be able or willing to take on their own. Reducing farmer risk is especially important in agroforestry programs, since working with perennial tree crops generally requires higher initial investment with longer-term returns than annual crops (Mukarutagwenda, 2018). Nonetheless, the limitations of this approach are many and significant, especially for agroforestry.

One of the issues with the ToT paradigm is that it promotes a top-down application of prototypes that are often ill-suited for wide-scale adoption (Chambers & Jiggins, 1987; Coe et al., 2014). Developed in research stations or validation plots, prototypes are designed and tested under controlled conditions and cannot possibly reflect the wide-range variation in the physical, economic and social conditions[49] of different farmers and their lands (Chambers and Jiggins 1987). Some clear examples are differences in labor access, topography, soils and access to inputs. (See Tables 1. and 2. in Appendix III for a list of typical contrasts in physical, economic and social circumstances between research stations, resource-rich farmers and resource-poor farmers). Thus, ToT structures do not necessarily deliver the "techno-fix" they intend to.

Project interviews in the Ecuadorian Amazon echo this criticism. For example, improved cacao germplasm (EET-95,EET-96 and EET-103), developed by INIAP and promoted by ATPA and PRCC, received mixed reviews in 80% of the interviews conducted. Both farmers and

[49] Some clear examples are differences in labor access, topography and access to inputs.

extensionists questioned the suitability of the improved varieties on a number of fronts: adaptability of clones to climate variations across counties; tolerance of clones to shade; compatibility of clones with other common perennials; number of pods produced per season; relative commercialization opportunities; and relative labor requirements (Burgoa 2019). The mixed reviews speak to the limitations of importing technologies at the expectation that these will stick in every situation.

Though these limitations might be a generalized concern in expert-led innovation in agriculture, it should be noted that developing prototypes is *especially difficult* when it comes to multi-variable, complex agroforestry systems, where numerous tree-crop-animal interfaces may occur on different time horizons. Diversified agroforestry design can be particularly intricate and risky: beyond conventional site selection considerations, the interplay of multiple farm elements almost always gives rise to biophysical competition for physical space, water, nutrients and light, etc. (Jose, 2005; Sanchez, 1995). Synergies are not guaranteed[50]. And since any mistakes in the a-priori selection and layout of trees will be difficult to correct in the future, careful selection, pairing and (temporal and spatial) arrangement of trees, crops and/or animals are not decisions to take lightly. Even if we chose to ignore social and economic factors in agroforestry design (which we should not), designing systems that balance vertices of competition and complementarity to the farmer's benefit in farmers' lands could not possibly follow a single

[50] Agroforestry science and knowledge in the last three decades has acknowledged this difficulty, and attempts have been made at developing decision-support tools – such as *WaNulCas* and *ShadeMotion* - that model the dynamic biophysical performance of a given set of tree-soil-crop arrangement (van Noordwijk M et al., 2004). Though this computer software might improve the quality of technical backstopping, the fact remains that biophysical modelling alone does not produce robust systems.

formula. For all the reasons described above, participatory approaches are a necessary ingredient of scaling-up agroforestry.

Endogenous, participatory approaches for scaling-up agroforestry

Farmer-Centered/Participatory/Endogenous traditions in agricultural R&E emerged in the 1980s as a reaction to the limitations of ToT, arguing that agricultural development comes from harnessing local resources and knowledge rather than importing expert-led innovation. (Bosworth et al., 2016; Chambers & Jiggins, 1987). Numerous research methods (e.g. Participatory Plant Breeding, Farming Systems Research, Rapid Rural Appraisal) and extension delivery methods (e.g. Farmer Field Schools, Digital Green Videos) have been devised to involve farmers in the process of defining and solving their agricultural problems (Black, 2000; SUSTAINET EA., 2010). Some of these methods have become mainstream with time. Even R&E systems that fundamentally follow a ToT model – like ATPA or PRCC – have embraced participation to some extent. International donors scan for stakeholder participation in project design as an indicator of inclusiveness and quality of development programs (Agarwal, 2001).

Hence, ATPA has tried to introduce participatory elements into its agroforestry work methodically and systematically; and in this regard, it differentiates itself from its counterpart - PRCC- and deviates from the larger ToT structure it exists in. Consider the main working tool of ATPA extensionists - the Integrated Management Plan (IMP). Technicians collect agronomic and socio-economic information by directly speaking to farmers and visiting their plots. They also have farmers sketch out a map of their current and future land use. These procedures are intended to provide the public officer with the necessary information to create a well-informed plan for an agroforestry reconversion. But field interviews and observations point to the ways in

which the IMP is not working as intended: extensionists spend hours collecting and entering agronomic and socio-economic data but the information is rarely synthesized. There is not always a correlation between the information collected and the proposed course of action. Farmers are asked to draw a map of their farm and choose one of the technological packages offered by ATPA (e.g. silvopasture, cacao, coffee) but an analytic process is missing. Some farmers are unaware that an Integrated Management Plan for their land exists and/or have a poor understanding of what that means. Moreover, high farmer-to-extensionists ratios turn the IMP into a burdensome protocol for technicians, too. All in all, it seems as if the IMP does less to facilitate the co-creation of agroforestry systems than one would expect. Employing participatory methods that help technicians through the complex decision-making in agroforestry design would be a step in the right direction.

Co-designing Agroforestry

Unfortunately, there are very few agroforestry-specific tools that put agroforestry science into practice while also considering farmer's priorities and farmers' knowledge about the roles, uses, advantages and disadvantages of different trees and crops. By far the most comprehensive yet simple - participatory yet technically sound - agroforestry extension tool is The Four-Step Guide for Analysis of the Shade Canopy**,** developed in 2018 by the Center for Tropical Agricultural Research and Education (CATIE) and Australian universities. (Access to the complete tool is available in Somarriba et al. (2018)).

Designed specifically for cacao-based agroforestry, this tool can aid technicians through critical factors in AF design *without providing recipes* (like the ToT model would). Thus,

designing the most appropriate shade canopy for a particular condition is the result of 20 diagnostic questions related to the following:

1) Farming household (.e.g. What economic, cultural or ecological goods and services do family members want to obtain from the cacao agroforest? How much is the family willing to invest?). Disaggregating by gender is advisable in order to identify gender-sensitive agroforestry options (D. Catacutan & World Agroforestry Centre, 2014)
2) Site conditions (e.g. soil fertility and water availability, slope and latitude)
3) The status of the main tree crop (.e.g. cacao genotype, phenological cycle, current cultural practices).
4) Traits and ecology of potential shade trees (e.g. diameter, crown height and form, and phenology of potential shade trees).

This diagnostic stage is followed by a trade-offs and synergies analysis, which can be done using three different techniques[51] (Somarriba, 2004; Somarriba et al., 2013; Somarriba, University of Melbourne, Australia, et al., 2018). The assessment is then compared to the farming family's objectives identified in Step 1. to decide on a design that is acceptable to the farming household. Like in Step 1., the assessment should , again, be disaggregated by gender to catch any significant differences in valuation of the practices and species. (See Figure 2. in Appendix III for a diagram of the framework).

[51] The guide walks technicians through "1) regression analysis, 2) competitive allocation of stand basal area (biomass or carbon) between cacao and the shade canopy plants and 3) simulation of shading patterns using open-source software like *ShadeMotion* (Somarriba, University of Melbourne, Australia, et al., 2018, p. 15)

The Four-Step Guide is neither too formulaic nor too vague. What is more, it is coupled with pedagogic material[52] - "The Shade Canopy of Cocoa" manual - that walks young and adult farmers through the diagnostic steps, presenting agroforestry science in a way that is digestible, and inviting interactive farmer participation[53] (Somarriba et al., 2013) (This support material is available at CATIE Project Competitiveness and Environment in Cacao Producing Territories of Central America (Central American Cacao Project). Together, these participatory agroforestry design methods are more likely to result in technically-sound and socially-informed agroforestry designs.

Co-learning about Agroforestry Management

Realizing positive benefits of agroforestry does not end with good design. Following-up on recently implemented agroforests, and supporting farmers in transitioning to a new *management regime,* is essential to a well-performing system. Think back to Chapter 3. and all the on-farm trade-offs, the techno-managerial complexities, that can arise with complex agroforestry. Here again, there are no recipes. Effective management regimes respond to the particular needs and capabilities of each farming household; minimize competitive dynamics and maximize synergies between the components of an agroforest; and are subject to continuous revision by farmers in response to new challenges (Gabriel, 2018; Jose, 2005; Sanchez, 1995). Those are the components of a resilient, adaptive management regime. For this, extension communication methods .i.e. instruction techniques and style, must follow pedagogical

[52] The farmer-friendly manual is available at (Somarriba et al., 2013)A series of cartooned manuals with other technical topics were created for CATIE's Central American Cacao Project and are available at catie.ac.cr
[53] Within the typology of participation, interactive participation implies that farmers have a voice and influence in decisions (Agarwal, 2001)

principles that successfully cultivate farmer-led innovation at the same time that they provide technical backstopping.

The Ecuadorian agroforestry programs can make improvements in this area, too. So far, the instruction techniques and style of ATPA and PRCC are high on technical backstopping (.i.e. focus on delivering management recommendations) but relatively low on farmer participation and pedagogy[54]. The programs' follow a standard Training & Visit (T & V) system; that is, extensionists meet with (usually) individual producers to train them on a variety of crop management topics, including planting, use of biofertilizers, pruning and post-harvest management (Burgoa 2019). Training usually consist of lectures and/or on-farm demonstrations of "best management practices."

Not only is the Training and Visit system difficult to sustain because the extension officer high extensionist-to-farmer it also lacks pedagogic blueprints for understanding key cross-cutting issues that make robust management regimes. These issues can be divided in three questions:

1) How do farmers learn to critically think and problem-solve for themselves? Interviews and field observations showed that farmers learn through observing their neighbors (other farmers), on-farm experimenting with their own innovations at a small scale, and by discussing ideas with people they trust. Take into account that the long life cycle of trees means agroforestry learning occurs over a longer time span. Extension systems should create multi-year

[54] This assessment is based on observation and field interviews – I did not conduct a formal evaluation of the degree to which targeted learning outcomes occur as a result of training.

learning opportunities that cultivate critical inquisitiveness and that correspond to farmers' primary modes of knowledge and skills acquisition.

2) What are the implications, responsibilities and difficulties of creating learning spaces for historically marginalized groups (e.g. women and Shuar indigenous people)? Though no obvious gender bias was detected in the data, almost 70% of ATPA and PRCC technicians (who are primarily male and mestizo) feel there are "cultural barriers" that make Shuar farmers less likely to experiment and adopt new practices.Thus, extension systems should aim to have an anthropological understanding of the people they work with and a social equity vision for both moral and instrumental reasons[55].

3) *How do we co-learn and co-adapt to climate change threats?* Nearly 40% of the farmers that were interviewed registered and predicted adverse effects[56] of climate change on agricultural livelihoods. In contrast, only 11% of technicians identified inter-relationships[57] between climate change and cacao agroforestry. As mentioned in Chapter 3, most extension agents see climate change as a real yet nebulous concept. Extension systems will need to methodically integrate climate change into their agendas in order to scale up the positive benefits of agroforestry for long lasting impact.

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[55] The latter is important because the omission of cross-cutting variables, such as gender and ethnicity, into agroforestry training is shown to reinforce or exacerbate social disparities and slow down agricultural development (Gatzweiler & von Braun, 2016, Chapter 1; Mathez-Stiefel et al., 2016).

[56] The most common adverse effects were: less availability of firewood; floods or droughts in rivers and streams; time and difficulty in preparing the ground for planting; time and ease of pruning for cocoa and coffee; time and ease of harvesting and drying cocoa, coffee and peanuts; increase in competitive weeds that reduce production and require more handling; increase in diseases that affect cacao and cinnamon.

[57] Some mentioned changes in the fermentation and/or drying process of cacao and coffee; increase in weeds, pests and diseases; more seasonal variation.

ATPA recognizes these gaps and intends[58] on redesigning the training curriculum to better address the learning needs of their audience. One way in which both ATPA and PRCC could accomplish this is by implementing the Four-Step Guide (and the pedagogic material that supplements it) in conjunction with well-known techniques like Farmer Field Schools (FFS), consistent with the phenology and life stages of the trees. The FFS approach is an educational structure where 20-30 farmers make regular field observations and use their findings, their knowledge and experience, to judge for themselves, what management practices are needed. Farmers meet with extensionists and other farmers throughout the cropping cycle to discuss constraints and innovations. During these on-farm, laid-back meetings, technicians illustrate basic biological, ecological and agronomic concepts and also facilitate a discovery-learning process through small-scale experimentation[59] with management practices. Visits to other farmers' plots encourage horizontal and network-based learning (SUSTAINET EA., 2010). To this end, countless manuals[60] on the principles, implementation steps, techniques and facilitation skills of FFS have been developed, including protocols for addressing the needs of marginalized groups[61]and for co-learning about climate change and its impacts on farming livelihoods[62]. ATPA and PRCC, and other agroforestry programs, can select, combine and adjust these extension manuals to fit the specific needs of the population they are working with.

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[58] ProAmazonia has assigned a Gender Specialist to the case and ATPA is developing a Farmer Field School curriculum.

[59] The literature recognizes that on-farm, small-scale experimentation is crucial in agroforestry to manage the risk of larger-scale, long-term investment and to discover "best-fit" agroforestry management regimes (Coe et al., 2014; Mukarutagwenda, 2018).

[60] Comprehensive manual with curriculum examples are available at David et al. (2006) and SUSTAINET EA. (2010). The World Bank and FAO have also created extension support material for the FFS approach.

[61] Catacutan & The World Agroforestry Centre (2014) have created a Gender Analysis for Agroforestry that could be employed in the Needs Assessment stage of FFS design.

[62] The International Institute for Environment and Development (IIED) (2009) provides many participatory tools for climate change analysis and disaster risk reduction.

This chapter has dissected the premises, tools and structure of exogenous and endogenous approaches to agricultural development, showing the relative usefulness of these perspectives for research and extension delivery. Properly designing and learning to manage AFS is an arduous, personalized and iterative process – this is one of the mains reasons why the ToT model in place is unsuitable for the work at hand. Another reason is that ToT instruction methods simply lack key curriculum components (e.g. gender and social inclusion) and pedagogical protocols that are morally and instrumentally necessary for achieving the desired outcomes. While outside technical backstopping remains critical, a Farmer-Centered approach is absolutely vital to this work.

CHAPTER 6

PUTTING IT ALL TOGETHER: AGRICULTURAL INNOVATION SYSTEMS

Mixed Exogenous-Endogenous approaches: the Agricultural Innovation System

In their book *Farmer First Revisited,* Scoones et al. reflect on the achievements and failures of the Farmer-Centered movement since its inception in the 1980s, and conclude that there is a "need to move beyond a concentration on the interaction between "farmers" and technologies" to a wider systems perspective" (Scoones et al., 2009, p. 1). Indeed, new directions have emerged to address the blind spots of both Tot and Farmer-Centerd/Participatory models – to address the systemic bottlenecks that have neither a "techno-fix" nor a "participation-fix." This chapter makes the concluding argument that a negotiated approach of endogenous and exogenous views of agricultural rural development, encapsulated by the Agricultural Innovation System (AIS), is best suited for making agroforestry scalable. In conjunction with tools presented in previous chapters, the theory and methods of AIS offer a more comprehensive lens through which to analyze and address the barriers and opportunities of agroforestry.

Barriers in scaling-up agroforestry

Together, the literature and the ATPA/PRCC case study have showcased why agroforestry – despite its well-researched benefits – does not always yield the expected outcomes and is difficult to scale-up. This paper has, thus far, focused on four main types of barriers with several interrelated causes and effects:

1) Barriers related to agroforestry ambitions vs. agroforestry realities: the inconvenient truth is that agroforestry is not all equal, it is not always advantageous to farmers and it is not

always beneficial to the environment. Romanticizing agroforestry and seeing it as a monolith gets in the way of orchestrating the necessary conditions for specific agroforestry practices to thrive where they are needed and wanted.

2) Barriers in program management: there is a need to address programmatic discrepancies about key operational definitions and/or practices (e.g. agroforestry, landscapes, climate-smart agriculture). The root causes of these discrepancies – diversity of agroforestry types, socio-ecological and climate uncertainty, research gaps or debates – require different management approaches. Co-learning should be a guiding principle of all programmatic activities.
3) Barriers for well-suited agroforestry design: Full benefit from agroforestry is only possible when farmers adopt systems (.i.e. crop combinations and crop management practices) that respond well to the fine-scale variation in sites' agroecological limitations, individual preferences and socio-economic realities (Coe et al. 2014). Agroforestry design is difficult in and of itself because of the interplay in tree-crop-animal interfaces and particularities of each farming household; and becomes *even more difficult* when programs strictly follow a top-down, Transfer-of-Technology model.
4) Barriers for agroforestry management and pedagogy: Agroforestry management is a learning-based process contingent on the quality and inclusiveness of agroforestry pedagogy. Agricultural instruction methods that follow a conventional Training and Visit system have blind spots around social equity and climate action. They neither match the realities of agroforestry practice nor capture the psycho-social and cultural aspects of knowledge acquisition in farming communities. Agroforestry pedagogy needs to be

multi-year, experiential and critical, based on social networks, and methodical about cross-cutting issues in order to build resilient and equitable systems.

These barriers are common across regions and institutions, but the list does not end there. A number of other cross-sectoral blocks with no clear cut solutions also impede scaling-up processes, as explained below.

The last type of barrier: Systemic Bottlenecks

Out of all the farms visited, at least 25% had not received any maintenance in the last 1 or 2 years. When asked why they had stop investing time and resources in their recently established cacao agroforestry plots, farmers expressed 'learned helplessness' about the economic structures that they are embedded in and that they have no control over: cacao agroforestry (regardless of the shade gradient) is simply not as economically rewarded as other farm enterprises are (e.g. cattle-ranching, dragon fruit and sugar cane). They mentioned their farms' high production costs and low revenues, especially for complex or diversified agroforestry (as explained in Chapter 3) but also for simpler agroforestry types with higher cacao volumes. With little to no markets for crops other than cacao and with fluctuating international cacao prices, cacao agroforestry is – for some farmers´ economic point of view – unviable.

Almost 90% of extensionists, too, and even management staff expressed the urgent need for differentiated commercial avenues that reduce the opportunity-cost of cacao cultivation in general and of multi-output agroforestry farms in particular. Despite ATPA and PRCC efforts to promote non-timber forest products in regional farmers' markets, Amazonian products with commercial potential face many market barriers. Beyond having an underdeveloped national market, they may be difficult to harvest (e.g. *Mauritia flexuosa)*, highly perishable (*Bactris gasipaes)*, produce in low quantities *(Ocotea quixos)* or have a slow maturity phase (*Genipa*

Americana) (Jarrett et al., 2017). Though these products might still be valuable to farming communities for the other services they provide, the reality is that farmers seeking to increase their cash income will respond to outside market signals. And, the way things are today, the market signals homogeneity, not multi-functional agroforestry.

Public interventions to offset the economic deficits of cacao agroforestry have primarily focused on trying to get organoleptic price premiums for "fine or flavor" cacao CN varieties (Jano & Mainville, 2007). However, is estimated that only 30% of small-scale farmers in Ecuador actually benefit from specialty prices, as most farmers sell directly to local intermediaries who do not pay a differentiated price based on quality (Díaz-Montenegro et al., 2018; Jano & Mainville, 2007). ATPA has also agricultural and gastronomic fairs in large cities, such as Quito and Cuenca, to promote Amazonian products; and has initiated a commercial agreement with Golden Farm company to create markets for non-timber agroforestry products (L. Trujillo, personal communication, January 1, 2020). Other incentive systems, such as Payments for Ecosystem Services (PES)[63] in the form of carbon credits, Organic certifications, and Zero-Deforestation programs, have been proposed as alternatives to make ecologically-based systems more profitable but face similar problems along the value chain (Somarriba et al. 2013).

The private sector, too, has developed differentiated value chains for CN varieties at the domestic level with relative success. For example, national artisanal chocolate producers, such as *Republica del Cacao* and *Pacari*, have built a brand based on sourcing from small-holder, cacao agroforestry growers and preserving the genetic stock of native CN varieties. As such, they have

[63] Payments for Ecosystem Services (PES) in the form of carbon credits, have taken off in countries like Costa Rica but have yet to infiltrate the Ecuadorian value chain (Somarriba et al. 2013).

established intermediary-free relationships with farming communities that grow specialty cacao using agroforestry techniques (Ahmed & Arrisueno, 2015; Pacari, 2019.; Republica del Cacao, 2019). Also at the national level, *Ikiam* has developed domestic channels for commercializing value-added products made out of Amazonian Ishpingo (i.e. Amazonian Cinnamon) and Ungurahua (.i.e. palm tree used for oil), both of which are commonly used as shade-trees in cacao agroforestry (Fronteras, 2014). Domestic – local and regional – channels are valuable in that they generate more stable cash flows without having farmers rely on highly volatile global markets (Altieri & Toledo, 2011).

The commercialization of agroforestry products is a well-recognized systemic bottleneck. But it is only one[64] of many blocks in the transition to more diversified and perennial agricultural systems. Fieldwork for this paper and the literature clearly indicate that scaling-up agroforestry requires changes in "pricing systems, land-tenure, credit schemes, extension policy and organization of trade" (Mukarutagwenda, 2018; Schut et al., 2016, p. 4). What can we do to address these systemic bottlenecks? A first step is to acknowledge that the dominant Research & Extension theories (explained in the previous chapter) are limited in their scope of analysis; that they do little to distill the ripple effects of multi-scale changes and lock-ins over a long period of time. Agricultural Innovation Systems (AIS) theory is more equipped to guide to analysis of complex agricultural problems "beyond the farm-gate" (Scoones et al. 2009).

[64] Other systemic bottlenecks include effective credit schemes for community-based land tenure; weak institutional capacity of producer's associations; inadequate policy incentives; and susceptibility of public extension systems to budget changes. These were mentioned in interviews, as well as in the latest review on agroforestry barriers by Mukarutgwenda (2018).

Framework for Networked Innovation

Under the AIS[65] framework, agricultural development is a multidirectional process that unfolds within an *ecosystem* of a wide range of actors, sectors, and institutions (World Bank, 2006, p. 28). Any actor (e.g. farmer, extensionist, or scientist), sector (e.g. academia, businesses, or tech) or institution (e.g. private or public) can innovate in the network. An innovation can be technical, managerial, institutional, or political; it can be a small improvement, a recombination of existing ways of doing, or a brand new idea/product (Bock, 2016; World Bank, 2006). Innovation capacity is strengthened by investing in complementary ecosystem interactions that form a 'community of practice'. Unlike Transfer of Technology and Farmer-Centered/Participatory theories, AIS thinking is 'relational' at its core and takes a mixed endogenous-exogenous perspective of rural development. An analysis of networked innovation integrates different sectors, illustrated by the conceptual diagram in Appendix IV (Figure 3.)

A guide for diagnosing the different dimensions of problems, cross-level interactions and stakeholder groups in an AIS is available at Schut et al. (2015, 2016). The Rapid Appraisal of Agricultural Innovation Systems (RAAIS) is able to identify specific entry points for innovation across scales. Thereby, agroforestry programs and other relevant stakeholders can design a plan of action to change the structural conditions that enable or hinder agroforestry transitions.

Following the analysis of entry points, partner engagement models are one way in which different actors of the Innovation System can deliberate problems that require simultaneous

[65]A popular definition is: "A network of actors (individuals, organizations and enterprises), together with supporting institutions and policies in the agricultural and related sectors that bring existing or new products, processes, and forms of organization into social and economic use. Policies and institutions (formal and informal) shape the way that these actors interact, generate, share and use knowledge as well as jointly learn"(Aerni et al., 2015).

change across scales and participate in joint planning. For example, these engagement models, known as Innovation Platforms (IP) , Multi-Stakeholder Platforms (MSP), or Private-Public Partnerships (PPP), have been used to bring small farmers, traders, processors, supermarkets and others together around value chains. (Thiele et al., 2011). In the cacao industry, partner engagement platforms would likely involve not just ministries, scientific institutions and farmers associations, but also processing industries, civil society organizations, global companies, financial institutions, and marketing/commercial enterprise. (Ahmed & Arrisueno, 2015; Essegbey & Ofori-Gyamfi, 2012).

Partner engagement models are not all that foreign to ATPA and PRCC. Bridging mechanisms have been implemented in the past, in the form of "coffee roundtables." In fact, during the data collection period, three roundtables were held to discuss the feasibility of establishing a coffee collection center in the Amazon. It was observed, however, that group facilitation skills were missing and that no concrete agendas came out of these meetings, pointing to the reality that cooperation can be arduous. ATPA has also expressed interest in being part of the Canopy Bridge platform, "a global network and market place for connecting buyers and sellers of sustainable products" (*Canopy Bridge*, 2018; L. Trujillo, personal communication, January 1, 2020). Bridging mechanisms and "consensus-building efforts" are successful under certain conditions[66] (e.g. the presence of a skilled facilitator) and should follow structured procedures towards making multi-variable decisions in the face of uncertainty (Gregory et al., 2001). A review of partner engagement models, their limitations, design criteria

[66] Not all challenges require a multi-stakeholder platforms, some problems are solved best unilaterally. Garard et al. (2018) has identified five elements of success in such platforms: "(1) the selection of participants relevant to the topic and conducive to positive interactions, (2) openness as an attitude in both organizers and participants, (3) facilitation of interactions and the role of the facilitator, (4) communication and transparency between organizers and participants, and (5) fostering dialogue between participants through various means." (p. 1).

and elements of success can be found in Kaner (2007), Schut et al. (2018), Garard et al. (2018) and Aerni et al. (2015). In the right situation, tapping into different niches of the Innovation System for cooperative action can be extremely promising.

Putting it all together: Scaling-up Agroforestry

The potential of agroforestry to address the multiple challenges this planet faces is undeniable, but turning this into a reality is not an easy process. One thing is for sure, scaling-up agroforestry will involve a concerted effort of co-learning, co-adapting, and co-managing. Achieving the best possible short and long-term outcomes based on current knowledge will require changes in mindsets and attitudes, methodological shifts in the science-to-action bridges, and the involvement of actors outside of the conventional Research and Extension institutions. As agroforestry takes policy priority and agroforestry programs become the recipient of more multilateral funding, the following considerations will be of use:

1. The plasticity of agroforestry forms is best exploited when field extensionists combine participatory methods and technical backstopping to help farmers identify and analyze suitable agroforestry options. An essential technical tool for realizing the potential benefits of cacao-based agroforestry systems is the Four-Step Guide for Analysis and Design of the Shade Canopy in Cocoa-Based Agroforestry Systems (Somarriba, University of Melbourne, Australia, et al., 2018).
2. Sustained, positive agroforestry benefits are possible when researchers and field extensionists know how to utilize methods that incorporate social inclusion into their design, implementation and training activities, adapting tools such as Gender Analysis in Agroforestry (D. Catacutan & World Agroforestry Centre, 2014) and Intersectionality Analysis for Agroforestry Landscapes (Colfer et al., 2018) to the local context.

3. Farmers' knowledge is catalyzed and their innovations amplified when agroforestry extensionists are trained in pedagogical methods that have a sensitive appreciation for farmers' knowledge and analysis and are able to cultivate small-scale experimentation and social learning. Farmer Field Schools (SUSTAINET EA., 2010), Mother-Baby Trials (Gonsalves et al., 2005) and even participatory videos (Sylvester, 2015) are useful methods *if* extensionists have the training and resources available to conduct these activities.
4. Sustained positive benefits of agroforestry are catalyzed when researchers, extensionists and farmers co-learn about climate change. Farmer Field Schools can be adapted to include Climate Change modules, known as Climate Field Schools (CFSs) (IIED, 2009)**.** Farmers need to be able to inform the climate change agenda of research institutions and climate change science can be combined with Community-Based Adaptation to Climate Change (CBA) strategies in order to cross-reference imperfect climate science with rural people's technical knowledge (IIED, 2009).
5. Systemic bottlenecks in scaling-up agroforestry demand joint action with actors that are outside of the traditional science-to-action bridging institutions'. Rapid Appraisal of Agricultural Innovation System (RAAIS) can help identify leverage points and design action plans. Partner engagement models such as Innovation Platforms (IPs) or Multi-Stakeholder Platforms (MSPs) can be promising when properly designed and facilitated (Garard et al., 2018; Kaner et al., 2008; Schut et al., 2018)**.**

As pioneers in the field, ATPA and PRCC aim to directly benefit 218,440 producers in the Ecuadorian Amazon through the implementation of agroforestry systems (Burgoa 2019;L. Trujillo, personal communication, January 1, 2020). In the process, they have come across several obstacles, most of which are probably common amongst agroforestry initiatives

elsewhere. The willingness of ATPA and PRCC to partake in this research-action process speaks volumes about their eagerness to improve their development practice and achieve these targets. As ATPA awaits its first evaluation of adoption figures and land cover targets, it has already begun the process of hiring staff to address some of the barriers outlined in this document, despite financial constraints. For example, they are in the process of developing a road map for implementing Farmer Field Schools with a climate focus, as well as for catalyzing agroforestry markets. Though there is much to learn still, these programs should be recognized for the vision and accomplishments of their work, which will serve as a reference point for initiatives elsewhere seeking to transform the agri-food system.

APPENDIX I

DATA COLLECTION INSTRUMENTS

Farm Transect Walk Guide

1. Type of cacao production system:

a) Cacao with specialized shade (e.g. cacao combined with fertilizer/legume trees such as various species of *Gliricidia*, *Inga*, *Leucaena*, *Erythrina*, *Albizia*)

b) Cacao with productive shade (e.g. cacao with a mono-specific canopy of palm tree, fruit, banana, or timber species)

c) Cacao with mixed (productive and specialized) shade

d) Cacao with rustic shade planted under thinned natural forest)

e) Cacao (monoculture) plantation

2. Cacao genotypes
3. Annual crops
4. Perennial crops
5. Spatial Arrangement:
6. Management Observation
7. Farmer-Led Innovation

Interview Guide (Extensionists)

1. What activities do you perform in your role as an extension technician for cacao farmers?

2. Describe the demographics of the farmers you work with. Do different farming households require different types of assistance?

a. In your opinion, what are they main problems facing farmers in this area?

3. Describe how you normally go about formulating Technical Reconversion Proposals

4. With regards to the Integrated Management Plan (IMP):

a. What are the typical characteristics of traditional cropping system that you work with? What species are present? In what arrangement? How are they managed?

b. Can you give examples of how ATPA helps improve these systems?

c. In your opinion, what are some important principles or factors for the design and management of an agroforestry system? Why?

5.What IMP information do you consider is most/least useful for formulating a successful Technical Reconversion Proposal?

6. In your opinion, what agroforestry practices have had the most/least impact and why?

7. From your point of view, farmers who have adopted the recommended systems have done so because…

8. From your point of view, farmers who have NOT adopted the recommended systems have not done so because…

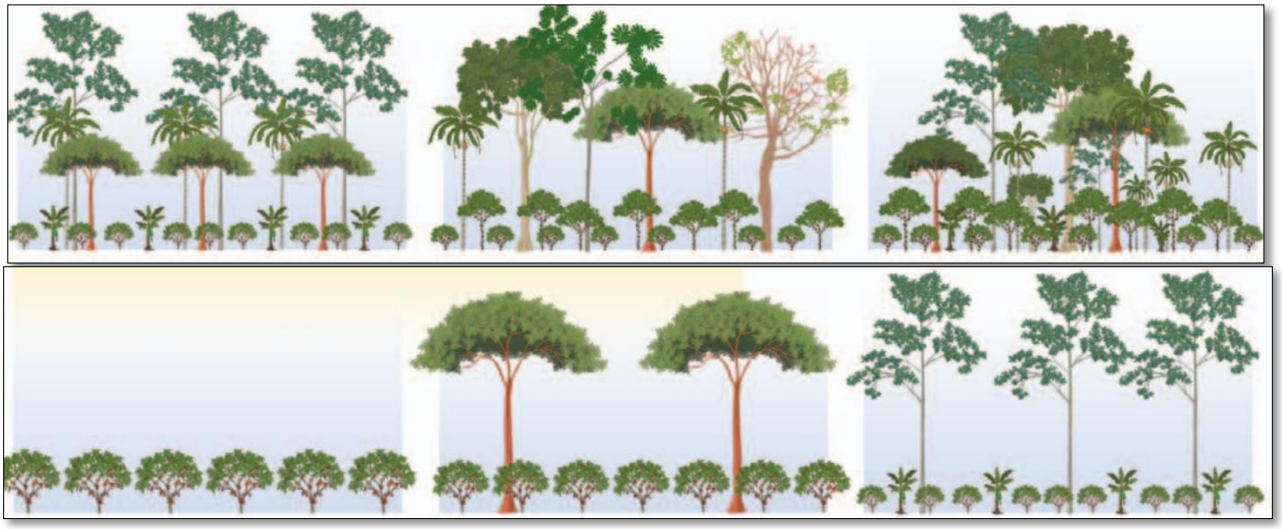
9.Is there any other factor that you consider affects (positively or negatively) your relationship or work with farmers?
10. Have any of the farmers that you have worked with adapted or invented agroforestry practices?

Interview Guide (Farmers)

1.Tell us about your farm and other any activities you would like to tell us about
a.Follow up probe: What crops do you grow? How do you grow them? Who helps you in the farm?
b.Follow-up probe: What do you do with the products? If you sell, who do you sell it to, how and for how much?
c. Follow-up probe: In your opinion, what are they main problems in your farm?
d.Follow-up probe: what other (non-farm) activities take up most of your time or energy?
2. Tells us about your involvement in the ATPA project
a. Follow up probe: are you familiar with the IMP or Technical Reconversion Proposal?
b.Follow up probe: what does your farm looked like before and after ATPA? What plans do you have for your farm?
3. What do the ATPA extensionist work on with you?
a.Follow-up probe: has she/he given you specific recommendations for how to change the farm? How were these delivered (e.g. oral or written/hands-on/in a group or individual)?
b.Follow-up probe: did you try out any these recommendations? Why or why not?
c.Follow-up probe: Did you have any success with these recommendations? Any failures?
d.Follow-up probe: Did you modify any of the recommendations? What was the outcome?
4. What would the ideal assistance include for you?
a. Follow-up probe: do you think extensionists understand your goals and limitations?
b.Follow-up probe: do you think you have different goals and limitations from your neighbors? Why?
5.Tell us about a time when you tried to change how you work in your farm or how you work with other people…
a.Follow-up probe: Have you or your neighbors had any new ideas or practices that you think are beneficial to your or your community?
b. Follow-up probe: Have you experimented with these? What was the result?
c.Follow-up probe: Have you discussed these with extensionists or community promoters? If yes, hoy did they respond?
6.Have you experienced the effects of climate change on your crops? How do you think this might affect your life in the future?
7. Demographics:
a. Gender:
b. Ethnicity:
c. Describe distance and method of transportation to nearest urban center

APPENDIX II

FIGURE 1. CACAO SYSTEMS WITH DIFFERENT SHADE LEVELS AND TYPES.
Annual crops may or may not be planted in the understory (Somarriba et al. 2013).



LIST OF PERENNIAL AND ANNUAL CROPS FOUND IN CACAO AGROFORESTRY

Guayacan *Tabebuia chrysantha*
Pechiche *Vitext gigantea*
Laurel Blanco *Cordia alliodroa*
Cedro *Cedrela odorata*
Papaya *Carica papaya*
Citrus *Citrus limon/ Citrus sinensis*
Avocado *Persea Americana*
Chirimoya *Annoa cherimola*
Guanabana *Annona muricata*
Zapote *Casimiroa edulis*
Arazá *Eugenia stipitata*
Ajo de Monte *Mansoa alliacea*
Fruta Pan *Artocarpus altillis*
Chonta *Bactris gasipaes*
Yafrí/Jack Fruit *Artocarpus heterophyllus*
Cajuil *Anacardium occidentale*
Mamey *Pouteria sapota*
Guayaba *Psidium guajava*
Canela *Licaria limbosa*
Borojó *Borojoa patinoi*
Coconut *Cocus nusifera*
Coffee *Coffea arabica*
Machetona *Inga spectabilis*
Guaba *Inga densiflora/ Inga edulis*
Paja toquilla *Cardulovica palmata*
Amarillo *Handroanthus chrysanthus*
Ceikia *unknown*
Caimito *Chrysophyllum caimito*
Huinchipo *Piptocoma discolor*
Rumbin *unknown*
Unguragua *Oenocarpus bataua*
Musa *Musa spp.*
Papa China *Solanum tuberosum*
Sugar cane *Saccharum officinarum*
Peanut *Arachis hypogea*
Pinneapple *Ananas comosus*
Cassava *Manihot esculenta*
Ginger *Zingiber officinale*

APPENDIX III

TABLES 1. and 2. PHYSICAL AND SOCIO-ECONOMIC CONDITIONS OF RESEARCH STATIONS VIS.A.VIS FARMERS. From Chambers and Jiggins (1987).

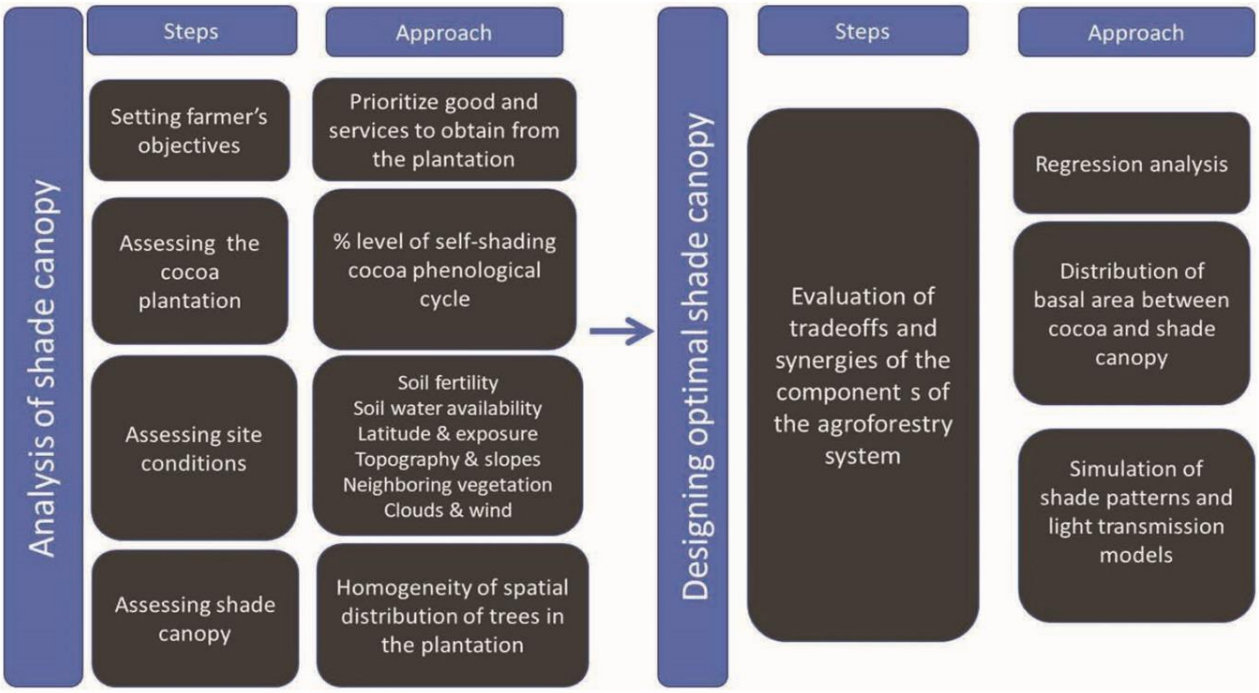
TABLE 1
Typical Contrasts in Physical Conditions
(Not all apply all the time, but most apply most of the time)

	Research experiment station	*Resource-rich farm (RRF)*	*Resource-poor farm (RPF)*
Topography	Flat or sometimes terraced	Flat or sometimes terraced	Often undulating and sloping
Soils	Deep, fertile, few constraints	Deep, fertile, few constraints	Shallow, infertile, often severe constraints
Macro- and micro-nutrient deficiency	Rare, remediable	Occasional	Quite common
Plot size and shape	Large, square	Large	Small, irregular
Hazards	Nil or few	Few, usually controllable	More common—floods, droughts, animals, grazing crops, etc.
Irrigation	Usually available	Often available	Often non-existent
Size of management unit	Large, contiguous	Large or medium contiguous	Small, often scattered and fragmented
Natural vegetation	Eliminated	Eliminated or highly controlled	Used or controlled at microlevel

TABLE 2
Typical Contrasts in Social and Economic Conditions
(Not all apply all the time, but most of the time)

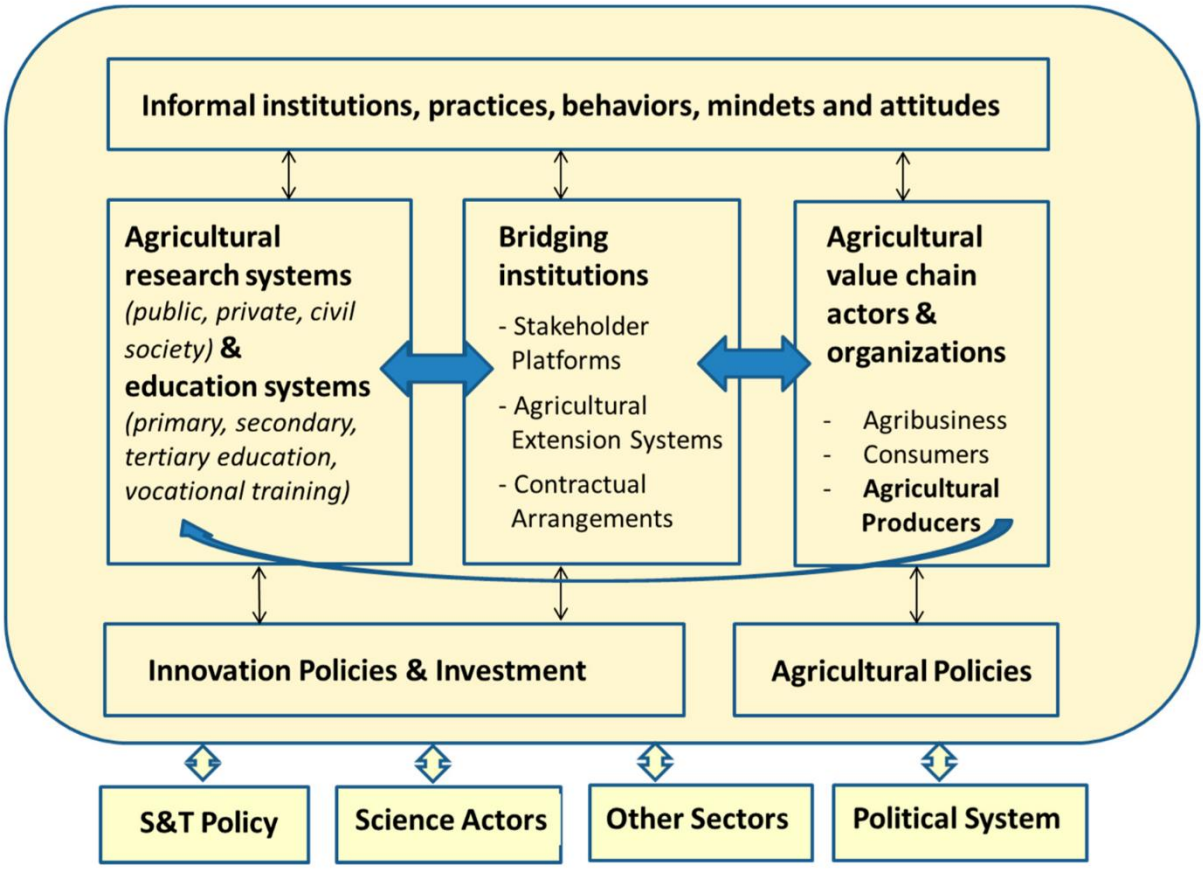
	Research experiment station	*RRF family*	*RPF family*
Access to seeds, fertilisers, pesticides and others purchased inputs	Unlimited, reliable	High, reliable	Low, unreliable
Source of seeds	Foundation stocks, and breeders' seed high quality	Purchased high quality	Own seeds
Access to credit when needed	Unlimited	Good access	Poor access and seasonal shortage of cash when most needed
Irrigation, where facilities exist	Fully controlled by research station	Controlled by farmer or by others on whom he can rely	Controlled by others, less reliable
Labour	Unlimited, no constraint	Hired, few constraints	Family, constraining at seasonal peaks
Prices	Irrelevant	Lower than RPF for inputs Higher than RPF for outputs	Higher than RRF for inputs Lower than RRF for outputs
Priority for food production	Neutral	Low	High
Access to extension services	Good but one-sided	Good, almost all material designed for this category	Poor access; little relevant material

FIGURE 2. FRAMEWORK WITH KEY STEPS INVOLVED IN THE ANALYSIS AND DESIGN OF A CACAO-BASED AGROFOREST. (For full access to the The Four-Step Guide for Analysis of the Shade Canopy read Somarriba et al. (2018)).



APPENDIX IV

FIGURE 3. DIMENSIONS OF AGRICULTURAL INNOVATION SYSTEMS from Aerni et al. (2015)



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