Growing agroecology in Nicaragua: Towards a multi-scale perspective on agroecological transitions

Katharina J.F. Schiller

Propositions

1. Technological Innovation Systems analyses of agroecological transitions do not adequately capture ecological change.
   (this thesis)

2. State-led agroecological transitions dilute agroecological principles.
   (this thesis)

3. Formulating propositions for a thesis is pointless.

4. Tiktok is the best medium for science communication.

5. Statistics are unreliable.

6. Environmental degradation is a more serious threat to humans than nuclear war.

Propositions belonging to the thesis, entitled
'Growing agroecology in Nicaragua: Towards a multi-level perspective on agroecological transitions'

Katharina J.F. Schiller
Wageningen, 14 February 2022

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Thesis

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Preface and acknowledgements

This PhD is much more than just a thesis and much more than the sum of its parts (a sentiment I assume many doctoral researchers share). My PhD journey has been amazing and unexpected, a wild ride and an incredibly steep learning curve, and has changed my life for the better in both the professional and personal senses. It has been very challenging and also extraordinarily fun. Although I cherish the experiences and memories made with many people whom I met over the course of my research - e.g. farmers and research assistants I was lucky enough to work with - several individuals have played especially important roles in the journey that led to the experience of researching and writing this dissertation.

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Laurens Klerkx, you brought me on board at KTI after mentoring me in the final round of the Erasmus Mundus PhD competition. You were the best first supervisor I can imagine - always supportive, always reachable, always with an idea when I had a question about my research, but also always critical, challenging me to solidify my argumentation, read more, think more intensely or connectively about issues, and really straightforward. I have passed on two bits of your wonderfully idiosyncratic advice to many others: "No one cares about your PhD but you" and "Kill your darlings" (in reference to paper-

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And of course, to my parents, family, and close friends that have supported me in innumerable ways in all the iterations of this journey - thank you from the bottom of my heart! A special and incredibly large thank you goes to my sister Cornelia Schiller Tremann for proofreading the entire thesis.

Summary (English)

The global agri-food production and consumption system (including agricultural production, livestock farming and fishing, food processing, food transport and storage, food retail, and food waste disposal) is already strongly impacted by climate change. Simultaneously, it contributes 30-34% of yearly anthropogenic greenhouse gas (GHG) emissions, with myriad negative environmental side-effects (e.g. soil degradation; water pollution) (Crippa et al. 2021; Filho et al. 2022). Increasing agri-food systems' resilience to climate change impacts while curbing GHG emissions implies a plethora of changes, including demand-side and social changes (e.g. revisiting supermarkets' standards; reduced meat consumption and increased plant-based diets) and supply-side changes including the use of digital technologies (e.g. remote sensing) and sustainable intensification of production through ecology-based means. Agroecological agri-food systems, accounting for the entire ecology of agri-food production and consumption systems, can be part of these solutions.

Transitioning from the current agri-food system to an agroecological one involves convoluted, long-lasting change processes in not just technologies and practices, but also e.g. ways of organizing, cultural and market preferences, value chain arrangements, financial set-ups, power relations between actors, knowledge distribution, and policies. Taking a prospective view, we cannot be certain that such transitions-in-the-making will progress to an overall transformation (e.g., complete change to agroecological agri-food systems), but we can identify the emergence of (new) practices, actors, networks, and framings that challenge and disrupt the status quo. Socio-technical frameworks, which account for technologies' social embeddedness, can help to structure analyses of such transition processes, and are beginning to be used to explain and derive recommendations for further supporting on-going agroecological transitions. Yet, empirical evidence of on-going transitions remains scarce.

This dissertation aims to contribute to this overall research gap (and several other research gaps within the agroecology and sustainability transitions literatures, identified in Chapter 1) by documenting and analyzing an on-going agroecological transition, specifically the involved processes, institutions, and stakeholders and their interactions. Through this research, the overarching question, "How do interactions between processes, institutions, and stakeholders produce and shape agroecological transitions, and which factors enable or limit the development of the agroecological transitions?" was answered. The specific focus is thereby on transitions from conventional to agroecological agri-food systems. The geographic focus is on Nicaragua, a country that has been a global forerunner in agroecology since the 1980s and has since then been in the process of an on-going transition to agroecology.

The overarching conceptual framework of the thesis is based in the multi-level perspective on sustainability transitions, and frames the transition to agroecology as the formation of a new agroecological niche within the conventional agricultural regime. Niches are spaces where networks of actors co-learn, i.e. they experiment together, mutually adapting eco-friendly innovations such as

agroecology. Regimes define the predominant 'way things are done' and comprise a complex structure of artefacts, institutions, and agents sustaining existing trajectories of development. Developments within and between niches and regimes occur against a background of broader social, political, economic, and cultural changes outside of actors' reach, the socio-technical landscape. The thesis dove deep into the development of the agroecological niche in Nicaragua. Because the emergence of agroecology in Nicaragua is tightly linked to historical and socio-political circumstances, a political economy-based context chapter provided background on relevant issues. Each of the three empirical chapters investigated how the agroecological transition is unfolding at a different location in the framework, and used a different analytical frame to do so. Quantitative and qualitative data was gathered in Nicaragua in 2014 and 2016-2018, using a variety of methods.

The dissertation includes six chapters, three of which are based on empirical research.

Chapter 1 is a general introduction that presents the topics of the research, the scientific state-of-the-art, and the research design.

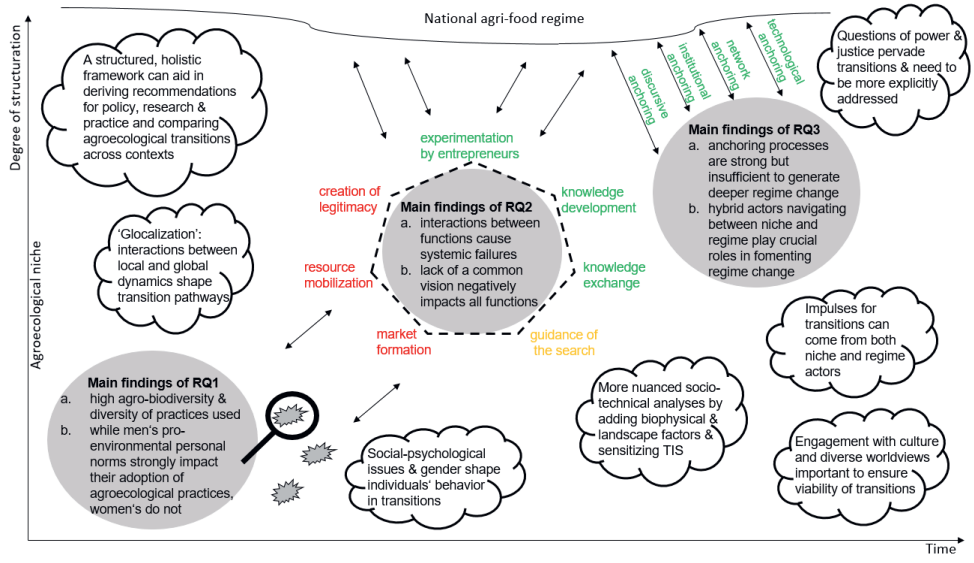
Chapter 2 is a political economy-based background chapter that provides context on Nicaragua's history as it pertains to the emergence and development of agroecology. Because socio-economic and socio-political events profoundly shaped agroecology's emergence and development in Nicaragua, this chapter gives information that the three empirical chapters build on.

Chapter 3 is conceptually located at the micro-level of individual farmers. It investigates farm-level transitions to agroecology through a social psychology lens, asking which agroecological practices are adopted by farmers and if a relationship exists between their gender, pro-environmental personal norms, and adoption of agroecological practices. Based on findings of a quantitative survey of 119 male and female farmers in northern Nicaragua, the study shows that both male and female farmers have adopted a broad array of agroecological practices and have high levels of agrobiodiversity on their farms. Interesting differences between male and female farmers were found concerning their pro-environmental personal norms and adoption of agroecological practices. While male farmers showed a consistently strong positive correlation between their pro-environmental personal norms and practice adoption, female farmers adopted agroecological practices at a steady frequency regardless of their pro-environmental personal norms, with some practice groups even showing slightly negative correlations. The findings point to the need for more gender-informed research and practice in agroecology and in broader climate change adaptation and environmental management.

Chapter 4 is conceptually located at the micro-meso level of individuals and organizations working to support agroecology in the emerging agroecological niche. Framing the agroecological niche as a new socio-technological innovation system (TIS), it uses a structural-functional analysis to investigate strengths and weaknesses in the ways innovation system structures (actors, networks, institutions, and infrastructures) function in support of agroecology. The TIS analysis finds that systemic blockages hindering the development of agroecology can be traced back to interactions between functions that are

only weakly executed. Particularly the core problem identified - the lack of a common vision for agroecology's development - is found to negatively impact all of the functions. Recommendations are made to strengthen the enaction of the functions to better support the transition to agroecology. In Chapter 6, these findings are revisited to paint a rich picture of the four so-called transformational failures, which go beyond the traditional rationales of market and structural system failures, and legitimize rationales for policy interventions in processes of transformative change such as agroecological transitions.

Chapter 5 conceptually explores niche-regime interactions at the border of the meso and macro levels. Using a framework that analyzes the 'anchoring' of niche elements into the regime, it investigates to what extent the niche has managed to change the regime. The findings show that while anchoring processes have effected shifts in various regime elements, they have been insufficient to generate deeper change within the regime. Rather, the regime has incorporated elements of agroecology without substantially providing for their implementation. The analysis highlights the importance of hybrid actors - those that move in both niche and regime spheres - and points to questions of how these actors are able to maintain their legitimacy in both spheres, relating to discussions on storylines and actions used by actors that intermediate between niche and regime to legitimize their roles in transition processes.



Chapter 6 synthesizes the study's empirical findings and debates what these findings mean for the fields of sustainability transitions and agroecology. The figure above highlights the empirical analyses' main findings and key conclusions drawn from a crosscutting analysis of the findings. These overarching

themes emerge in Chapter 6 when the empirical chapters' findings are considered jointly, and are further discussed in light of the agroecology and sustainability transition literatures. From this cross-cutting analysis, four concrete issues are identified that hinder agroecological transitions - policy mismatches and incoherence; weak knowledge on certain aspects of agroecology by different stakeholders; lacking markets for agroecological products; and a missing focus on gender issues - and implications derived for agroecological policy and practice. Recommendations are given for how these issues may be addressed by different stakeholder groups (national governments, civil society, and private sector).

Resumen (Español)

El sistema mundial de producción y consumo agroalimentario (que incluye la producción agrícola, la ganadería y la pesca, la transformación de alimentos, el transporte y almacenamiento de alimentos, el comercio minorista de alimentos y la eliminación de residuos alimentarios) ya se ve muy afectado por el cambio climático. Al mismo tiempo, contribuye al 30-34% de las emisiones antropogénicas anuales de gases de efecto invernadero (GEI), con innumerables efectos secundarios negativos para el medio ambiente (por ejemplo, la degradación del suelo y la contaminación del agua) (Crippa et al. 2021; Filho et al. 2022). Aumentar la resiliencia de los sistemas agroalimentarios a los impactos del cambio climático y, al mismo tiempo, frenar las emisiones de GEI implica una plétora de cambios, incluidos los cambios sociales y del lado de la demanda (por ejemplo, revisar las normas de los supermercados, reducir el consumo de carne y aumentar las dietas basadas en plantas) y los cambios del lado de la oferta, incluido el uso de tecnologías digitales (por ejemplo, teledetección) y la intensificación sostenible de la producción a través de medios basados en la ecología. Los sistemas agroalimentarios agroecológicos, que tienen en cuenta toda la ecología de los sistemas de producción y consumo agroalimentarios, pueden formar parte de estas soluciones.

La transición del sistema agroalimentario actual a uno agroecológico implica procesos de cambio complejos y duraderos no sólo en las tecnologías y las prácticas, sino también, por ejemplo, en las formas de organización, las preferencias culturales y de mercado, los acuerdos de la cadena de valor, las estructuras financieras, las relaciones de poder entre los actores, la distribución del conocimiento y las políticas. Desde un punto de vista prospectivo, no podemos estar seguros de que estas transiciones en curso avancen hacia una transformación global (por ejemplo, el cambio completo a sistemas agroalimentarios agroecológicos), pero sí podemos identificar la aparición de (nuevas) prácticas, actores, redes y marcos que desafían y alteran el statu quo. Los marcos sociotécnicos, que tienen en cuenta el arraigo social de las tecnologías, pueden ayudar a estructurar los análisis de estos procesos de transición y se están empezando a utilizar para explicar y formular recomendaciones para seguir apoyando las transiciones agroecológicas en curso. Sin embargo, las pruebas empíricas de las transiciones en curso siguen siendo escasas.

Esta tesis pretende contribuir a esta laguna general de la investigación (y a otras lagunas de la literatura sobre transiciones agroecológicas y sostenibles, identificadas en el capítulo 1) documentando y analizando una transición agroecológica en curso, en concreto los procesos, instituciones y partes interesadas implicados y sus interacciones. A través de esta investigación, se respondió a la pregunta general: ¿Cómo producen y dan forma a las transiciones agroecológicas las interacciones entre procesos, instituciones y partes interesadas, y qué factores permiten o limitan el desarrollo de las transiciones agroecológicas? De este modo, el enfoque específico se centra en las transiciones de los sistemas agroalimentarios convencionales a los agroecológicos. El enfoque geográfico se centra en Nicaragua,

un país que ha sido precursor mundial en agroecología desde la década de 1980 y que desde entonces ha estado en proceso de transición hacia la agroecología.

El marco conceptual general de la tesis se basa en la perspectiva multinivel de las transiciones hacia la sostenibilidad, y enmarca la transición a la agroecología como la formación de un nuevo nicho agroecológico dentro del régimen agrícola convencional. Los nichos son espacios donde redes de actores coaprenden, es decir, experimentan juntos, adaptando mutuamente innovaciones ecológicas como la agroecología. Los regímenes definen la "forma de hacer las cosas" predominante y comprenden una compleja estructura de artefactos, instituciones y agentes que sostienen las trayectorias de desarrollo existentes. La evolución dentro de los nichos y regímenes y entre ellos se produce en un contexto de cambios sociales, políticos, económicos y culturales más amplios que quedan fuera del alcance de los agentes, el paisaje sociotécnico. La tesis profundizó en el desarrollo del nicho agroecológico en Nicaragua. Dado que el surgimiento de la agroecología en Nicaragua está estrechamente vinculado a circunstancias históricas y sociopolíticas, un capítulo de contexto basado en la economía política proporcionó antecedentes sobre cuestiones relevantes. Cada uno de los tres capítulos empíricos investigó cómo se está desarrollando la transición agroecológica en un lugar diferente del marco, y utilizó un marco analítico diferente para hacerlo. Se recopilaron datos cuantitativos y cualitativos en Nicaragua en 2014 y 2016-2018, utilizando diversos métodos.

La tesis consta de seis capítulos, tres de los cuales se basan en investigaciones empíricas.

El capítulo 1 es una introducción general que presenta los temas de la investigación, sus contextos en la literatura científica y el diseño de la investigación.

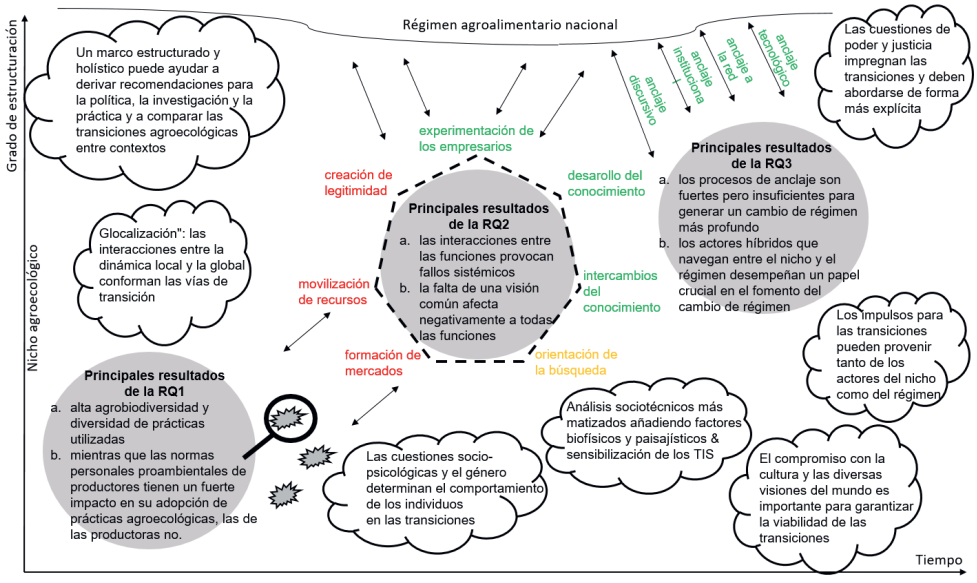
El capítulo 2 es un capítulo de antecedentes basados en la economía política que proporciona el contexto de la historia de Nicaragua en lo que respecta al surgimiento y desarrollo de la agroecología. Debido a que los acontecimientos socioeconómicos y sociopolíticos moldearon profundamente el surgimiento y desarrollo de la agroecología en Nicaragua, este capítulo proporciona información sobre la que se basan los tres capítulos empíricos.

El capítulo 3 se sitúa conceptualmente en el micronivel de los agricultores individuales. Investiga las transiciones a la agroecología a nivel de finca a través de una lente de psicología social, preguntando qué prácticas agroecológicas son adoptadas por los agricultores y si existe una relación entre su género, las normas personales pro-ambientales y la adopción de prácticas agroecológicas. Basándose en los resultados de una encuesta cuantitativa realizada a 119 agricultores y agricultoras del norte de Nicaragua, el estudio muestra que tanto los agricultores como las agricultoras han adoptado una amplia gama de prácticas agroecológicas y tienen altos niveles de agrobiodiversidad en sus explotaciones. Se encontraron diferencias interesantes entre agricultores y agricultoras en cuanto a sus normas personales proambientales y la adopción de prácticas agroecológicas. Mientras que los agricultores varones mostraban una fuerte correlación positiva entre sus normas personales proambientales y la adopción de prácticas, las agricultoras adoptaban prácticas agroecológicas con una frecuencia constante,

independientemente de sus normas personales proambientales, y algunos grupos de prácticas mostraban incluso correlaciones ligeramente negativas. Las conclusiones apuntan a la necesidad de una investigación y una práctica de la agroecología que tengan más en cuenta las cuestiones de género, así como de una adaptación al cambio climático y una gestión medioambiental más amplias.

El capítulo 4 se sitúa conceptualmente en el nivel micro-meso de las personas y organizaciones que trabajan para apoyar la agroecología en el nicho agroecológico emergente. Enmarcando el nicho agroecológico como un nuevo sistema de innovación sociotecnológica (SIT), utiliza un análisis estructural-funcional para investigar los puntos fuertes y débiles de las estructuras del sistema de innovación (actores, redes, instituciones e infraestructuras) en apoyo de la agroecología. El análisis TIS concluye que los bloqueos sistémicos que obstaculizan el desarrollo de la agroecología pueden remontarse a interacciones entre funciones que sólo se ejecutan de forma deficiente. En particular, el problema central identificado - la falta de una visión común para el desarrollo de la agroecología - afecta negativamente a todas las funciones. Se formulan recomendaciones para reforzar la ejecución de las funciones con el fin de apoyar mejor la transición a la agroecología. En el capítulo 6, se revisan estas conclusiones para esbozar un rico panorama de los cuatro denominados fracasos transformacionales, que van más allá de las justificaciones tradicionales de los fracasos del mercado y del sistema estructural, y legitiman las justificaciones de las intervenciones políticas en procesos de cambio transformacional como las transiciones agroecológicas.

El capítulo 5 explora conceptualmente las interacciones nicho-régimen en la frontera de los niveles meso y macro. Utilizando un marco que analiza el "anclaje" de los elementos del nicho en el régimen, investiga hasta qué punto el nicho ha conseguido cambiar el régimen. Los resultados muestran que, aunque los procesos de anclaje han producido cambios en varios elementos del régimen, no han sido suficientes para generar cambios más profundos en él. Más bien, el régimen ha incorporado elementos de la agroecología sin prever sustancialmente su aplicación. El análisis subraya la importancia de los actores híbridos -aquellos que se mueven tanto en la esfera del nicho como en la del régimen- y apunta a cuestiones sobre cómo estos actores son capaces de mantener su legitimidad en ambas esferas, en relación con los debates sobre las líneas argumentales y las acciones utilizadas por los actores que intermedian entre el nicho y el régimen para legitimar su papel en los procesos de transición.



En el capítulo 6 se sintetizan los resultados empíricos del estudio y se debate qué significan para los ámbitos de las transiciones hacia la sostenibilidad y la agroecología. En la figura anterior se destacan los principales resultados de los análisis empíricos y las conclusiones clave extraídas de un análisis transversal de los resultados. Estos temas generales aparecen en el capítulo 6, cuando se examinan conjuntamente los resultados de los capítulos empíricos, y se analizan más a fondo a la luz de la literatura sobre agroecología y transiciones sostenibles. A partir de este análisis transversal, se identifican cuatro cuestiones concretas que obstaculizan las transiciones agroecológicas -desajuste e incoherencia de las políticas; escaso conocimiento de determinados aspectos de la agroecología por parte de los distintos interesados; falta de mercados para los productos agroecológicos; y falta de atención a las cuestiones de género- y se derivan implicaciones para la política y la práctica agroecológicas. Se ofrecen recomendaciones sobre cómo pueden abordar estas cuestiones los distintos grupos de interesados (gobiernos nacionales, sociedad civil y sector privado).

Figures

Tables

Acronyms of organizations

Abbreviation	Spanish name	English name
ADAR	Asociación para el Desarrollo Agroecológico Regional	Association for Regional Agroecological Development
ADDAC	Asociación para la Diversificación y el Desarrollo Agrícola Comunal	Association for Development and Diversification of Agricultural Communities
ASDENIC	Asociación para el Desarrollo de Nicaragua	Association for the Development of Nicaragua
ASI	Alianza Semillas de Identidad	National Alliance "Seeds of Identity"
ASOCODE	Asociación de Organizaciones Campesinas de Centroamérica para la Cooperación y el Desarrollo	Central American Association of Rural Organizations for Cooperation and Development
ATC	Asociación de Trabajadores del Campo	Rural Workers' Association
CAN	-	Community Agroecology Network
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza	Tropical Agricultural Research and Higher Education Center
CLOC	Coordinadora Latinoamericana de Organizaciones del Campo	Regional Coordination of Latin American Rural Organizations
GISSAN	Grupo de Interés sobre Soberanía y Seguridad Alimentaria y Nutricional	Interest Group on Food and Nutritional Sovereignty and Security
GPAE	Grupo de Promoción de Agricultura Ecológica	Group for the Promotion of Ecological Agriculture
GRUN	Gobierno de Reconciliación y Unidad Nacional	Government of Reconciliation and National Unity
IAN	Instituto Agraria de Nicaragua	Nicaraguan Agricultural Institute
IICA	Instituto Interamericano de Cooperación para la Agricultura	Interamerican Institute for Agricultural Cooperation
INRA	Instituto Nicaragüense de Reforma Agraria	Nicaraguan Institute of Agricultural Reform
INTA	Instituto Nicaragüense de Tecnología Agropecuaria	Nicaraguan Institute of Agricultural Technology
IPSA	Instituto de Protección y Sanidad Agropecuaria	Institute of Agricultural Protection and Health
IRENA	Instituto de Recursos Naturales	Nicaraguan Institute for Natural Resources
LVC	La Via Campesina	La Via Campesina

Abbreviation	Spanish name	English name
MAELA	Movimiento Agroecológico de América Latina y el Caribe	Agroecological Movement of Latin America and the Caribbean
MAG	Ministerio Agropecuario	Ministry of Agriculture
MAGFOR	Ministerio Agropecuario y Forestal	Ministry of Agriculture and Forestry (defunct; now MAG)
MAN	Movimiento Ambiental Nicaragüense	Nicaraguan Environmental Movement
MAONIC	Movimiento de Productoras y Productores Agroecológicos y Orgánicos de Nicaragua	Movement of Agroecological and Organic Producers of Nicaragua
MARENA	Ministerio de Medio Ambiente y de los Recursos Naturales	Ministry of Environment and Natural Resources
MEFFCA	Ministerio de Economía Familiar, Comunitaria, Cooperativa y Asociativa	Ministry of Family, Community, Cooperative and Associative Economy
MIDINRA	Ministerio de Desarrollo Agropecuario y Reforma Agraria	Ministry of Agricultural and Livestock Development and Agrarian Reform
PCAC-UNAG	Programa Campesino a Campesino de la UNAG	Farmer to farmer program of UNAG
RENICC	Red Nicaragüense de Comercio Comunitario	Nicaraguan Network of Community Commerce
SIMAS	Servicio de Información Mesoamericano sobre Agricultura Sostenible	Mesoamerican Information Service on Sustainable Agriculture
SOFAMA	Asociación para el Fomento de la Agricultura y el Medio Ambiente	Association for the Promotion of Agriculture and the Environment
UNA	Universidad Nacional Agraria	National Agrarian University
UNAG	Unión Nacional de Agricultores y Ganaderos	National Union of Farmers and Ranchers
UNAN-Léon	Universidad Nacional Autónoma de Nicaragua, León	National Autonomous University of Nicaragua in León

Chapter 1: Introduction

1.1 Prelude

Doña Josefina lives with five of her grandchildren, all below the age of fifteen, and one daughter with a long-term illness on her 1.5 manzana[1] farm outside of the departmental capital, Waslala, in Nicaragua's central hills. She was showing me how she makes her own fertilizer by mixing farm residues with pulverized carbon powder, soil from the field, and a few other ingredients, then letting the mixture ferment (see also MAONIC 2015; 2016; Morales Herrera 2021). Two sows with their piglets around them enjoyed the shade of the side of the barn. Sundry chickens picked at the dirt and moved towards the shrubs at the side of the barn, weaving their way single-file through the fence slats to the greener grass beyond. On the other side of the yard, herbs hung to dry on the fence and behind that, laundry dried on wires between fruit trees. Doña Josefina grows cocoa as part of a local cooperative, and harvests beans, maize, bananas, and more than 20 different types of crops, including fruits, vegetables, and medicinal herbs. As we walked down to the cocoa trees planted in a dell behind her house, her machete swung out to behead a poisonous snake that was crossing our path. She told me how she had combated disease on her cocoa trees by selectively cutting branches to allow more air circulation and that her cocoa harvest was looking good so far this year. Since her husband died eight years ago, she manages the farm by herself; two daughters work in other, further away cities and the grandchildren live with her. As much as possible, she farms agroecologically because it's better for the earth, producing more succulent crops, and better for her grandchildren who run around the farm, she explained to me. She does use chemical pesticides, but in emergencies only. Her farm was an organized riot of plants and animals occupying a plethora of spatial and temporal ecological niches. Besides learning so much from Doña Josefina that day on her farm, our hearts spoke to one another, as cheesy as that may sound, and I was overjoyed to meet her again a year later at the first National Agroecology Congress at a hotel on the outskirts of Managua, Nicaragua's capital, where she was participating as a representative of her cooperative. As we sat outside during breaks in the congress, we shared our excitement at the fact this congress, the first national agroecology conference organized by the Nicaraguan government, was taking place and that we were able to be among the 500 or so participants. During dinner, she mentioned that she was boarding a bus back to Waslala afterwards. She had already told me how, together with other farmers and extension agents from around Waslala, she had boarded a bus the night before to come to Managua. Doña Josefina's worldview, her warmth, her resilience, the physical and mental strength and knowledge that she embodied to organize and maintain her incredibly biodiverse house and farm and provide for her family have stayed with me since we met. She, and other farmers I have been lucky enough to meet and learn from in the course of my PhD journey, continue to inspire my research and practice.

The knowledge I gained from Doña Josefina and many other farmers and extension agents in central and western Nicaragua is the basis of this thesis on the growth of agroecology in Nicaragua - its on-

[1] Manzanas are Nicaragua's measure of land. 1 manzana is 0.7044 hectares or 7,044 m^2.

going agroecological transition. This first chapter provides a general introduction to the thesis. It begins by elaborating on the problem identified and on how the research addresses this, highlighting the central conceptual issues that frame the thesis and are addressed in the empirical chapters. The conceptual framework of the thesis is presented in section 1.4., and the contributions of the thesis to scientific debates are discussed. Next, the general research objectives and specific research questions are outlined, followed by a description of the research approach and a reflection on its limitations. An outline of the thesis concludes the chapter.

1.2 Introduction: Understanding and fostering agroecological transitions

1.2.1 What is agroecology and where does it come from?

The roots of agroecology lie in the ecological rationale of indigenous and peasant agriculture, which is still prevalent in many parts of the Global South, and in pockets of the Global North, today (Altieri 2002). Many agrarian societies have used what are now deemed agroecological practices for many centuries (Altieri et al. 2015). Such practices may typically integrate a diversity of animal and plant species, in complex combinations on the farm and in territories, thereby building functional farming and land-use systems (Pimbert et al. 2021). For example, Central Americans have used the 'milpa' system - the intercropping of maize, gourds, and beans - to produce food in low-nutrient tropical soils since at least Mayan times (Altieri 2002); modern integrated rice-duck-fish farming systems are based on techniques used across ancient Asia (Zheng et al. 2017).

Agroecology emphasizes systems thinking and ecological principles, and embraces both natural and social sciences (Francis et al. 2003). As agroecology is based in generating local solutions to local problems, it is knowledge-intensive, involving both formal and nonscientific knowledge systems (Méndez, Bacon, and Cohen 2012), and context-dependent (Tittonell et al. 2016; Utter et al. 2021). Hence, effecting agroecological transitions is complicated. Recognizing this, the agroecological literature has evolved from a plot- or field-level focus to understanding agroecology as "the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions" (Francis et al 2003, 100). As illustrated in Figure 1, the scientific discipline of agroecology has expanded from a focus on the ecology of an individual plot to the agroecosystem of the farm, further broadening to include insights from agrarian social thought and sociological theory (Sevilla Guzmán and Woodgate 2013) and the ecology of the whole agri-food system (Gliessman 2016; Lamine and Dawson 2018). Simultaneously, the understanding of agroecology has grown, to include not just agroecology as a science and as a set of farming practices, but also recognizing the central importance of the social movement and political aspects of agroecology (Sevilla Guzmán and Woodgate 2013; González de Molina 2013; González de Molina et al. 2019; Meek and Khadse 2020). This broadening of the scope of agroecology is reflected also in changes concerning research methods used by scientists

studying agroecology (Pimbert et al. 2021). Initially, methods were based in agronomy and quantitative ecology (e.g. comparative analyses of cropping systems, or analytic descriptions of species diversity). Qualitative research methods have been adopted more recently to better understand the social, economic, and political dynamics of agri-food systems. The methodological pluralism of current agroecological research reflects the large number of disciplines involved and agroecology's general transdisciplinary nature (HLPE 2019a).

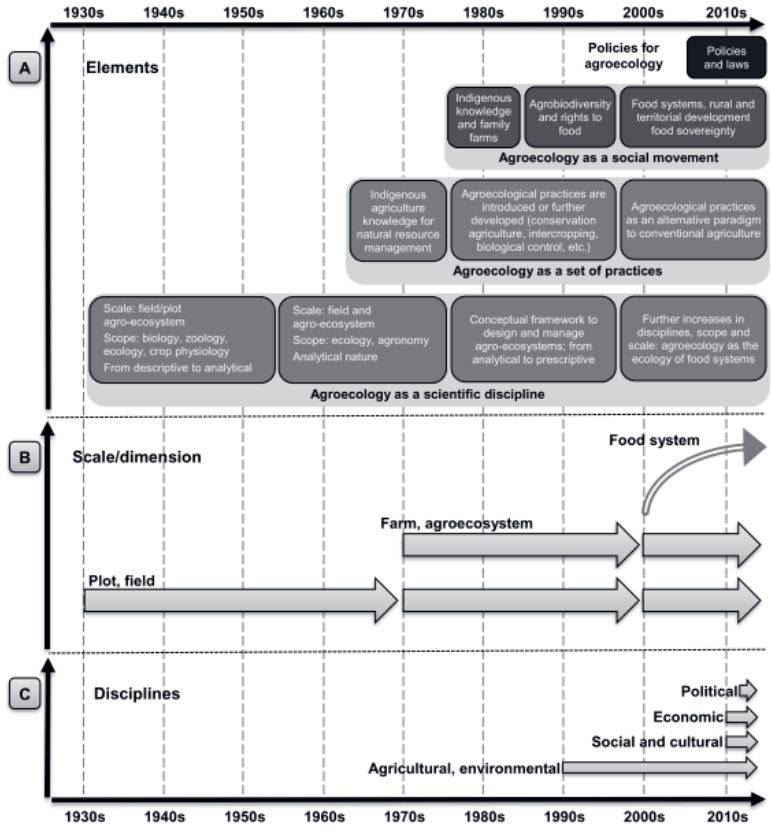


Figure 1: The evolution of agroecological thought and its different facets (HLPE 2019a, 35; Silici 2014; Wezel et al. 2009; Wezel and Soldat 2009)

1.2.2 Agroecology and its transformative potential

Nowadays, agroecological farming systems, utilizing ecological principles for the design and management of resilient, sustainable, and productive farms, have been identified as a promising alternative to the dominant input-intensive agro-industrial production model (FAO 2015; IPES-Food

2016; De Schutter and Vanloqueren 2016). While there is debate about the binary discourse on 'conventional' and 'alternative' forms of agriculture, and the global agri-food system is not monolithic but embodies a great diversity of forms of agricultural production (Sumberg and Giller 2022), it is undeniable that the current global agri-food system contributes an estimated 30-34% of annual global greenhouse gas emissions (Crippa et al. 2021; Tubiello et al. 2022). Agroecological systems may contribute to climate change mitigation, e.g. reducing greenhouse gas emissions by avoiding the use of fossil-fuel-based inputs and increasing soil carbon sequestration (Tuomisto et al. 2012; Kremen and Miles 2012; Stavi and Lal 2012; Rossing, Modernel, and Tittonell 2014). A growing body of work demonstrates that agroecological farming systems exhibit the high levels of diversity, productivity, and efficiency necessary to ensure the food supply of the growing global population in an environmentally friendly and socially equitable manner, while being more resilient to extreme weather events than conventional farming (Pretty, Morison, and Hine 2003; Altieri and Nicholls 2005; Francis and Altieri 2008; Flora 2010; Gianinazzi et al. 2010; Lin 2011; Koohafkan, Altieri, and Gimenez 2012; Kremen and Miles 2012; Kremen, Iles, and Bacon 2012; Bommarco, Kleijn, and Potts 2013; Wibbelmann et al. 2013; Dumont et al. 2014; Ferguson and Lovell 2014; Timmermann and Félix 2015; Altieri et al. 2015; Capellesso et al. 2015; Duru et al. 2015; Lescourret et al. 2015; Ponisio et al. 2015; Garbach et al. 2017; IPES-Food 2016; Zimmerer and Vanek 2016; D'Annolfo et al. 2017; Palomo-Campesino, González, and García-Llorente 2018; Dainese et al. 2019; HLPE 2019a; IPCC 2019; van der Ploeg et al. 2019; Herren, Haerlin, and IAASTD + 10 Advisory Group 2020; Leippert et al. 2020; Anderson et al. 2021; Bezner Kerr et al. 2021; Deaconu et al. 2021; Jones et al. 2021).

Agroecology is now considered, e.g. by the International Panel on Climate Change (IPCC) and the Food and Agriculture Organization of the United Nations (FAO), as an innovative agricultural system that can aid in answering two of the climate crisis' most pressing issues on global agricultural production (FAO 2015; FAO et al. 2018; FAO 2018b; IPCC 2019). First, the global agri-food system's massive contribution to the climate crisis, in forms of e.g. greenhouse gas emissions and water and soil pollution. Second, the vulnerability of agri-food systems to the impacts of climate crises, such as changing weather patterns and the changing of growing seasons due to changing temperatures. Hence, agroecology may currently be considered as an 'innovative' solution[2] to both of these issues through the construction of ecosystem-services-based, productive, diversified, and resilient agri-food systems. Agroecology's potential to be part of the solution for pressing global problems, and its potential to contribute to the realization of equitable international green growth goals such as the Sustainable Development Goals, is widely acknowledged, including by the United Nations' High-Level Panel of Experts on food security and nutrition (HLPE 2019a), the International Panel of Experts on Sustainable Food Systems (IPES-Food 2016), the International Assessment of Agricultural Knowledge, Science and Technology for

[2] It is important to note that innovative practices can be something completely new, but can also be based on traditional principles or techniques that have not been studied much (Uphoff 2002) and have been newly adapted into an improved novelty (Wezel et al. 2014). In this sense, agroecology is a 'retro-innovation', purposefully reviving historic practices, ideas, and technologies (Zagata et al. 2020).

Development (IAASTD 2009; Herren, Haerlin, and IAASTD + 10 Advisory Group 2020), the International Platform for Biodiversity and Ecosystem Services (IPBES 2019), the IPCC (IPCC 2019), and the FAO (FAO 2015; FAO et al. 2018; FAO 2018b).

Yet, although many international institutions and panels have recognized agroecology's potential to be part of the solutions for these pressing global problems, many of the principal actors of the international agricultural sector (i.e. research organizations and consultative panels, many national governments, the agro-chemical and breeding industries, the major trade and marketing outlets, and many academics) have not (Tittonell et al. 2016). Agroecology remains deeply contested by proponents of industrial agri-food systems (Pimbert et al. 2021). Due to historical and recent developments, the global agri-food system is heavily concentrated along all parts of the food chain (Clapp 2021) and is estimated to be worth roughly $8 trillion annually (van Nieuwkoop 2019). The current agri-food system is locked into an unsustainable path due to the embedded nature of technologies, misaligned institutional settings, infrastructural rigidities, incongruous research and innovation priorities, individual attitudes and culture, and broader political economy factors (Conti, Zanello, and Hall 2021). Its success is contingent on maintaining homogenous production environments with large-scale commercial farm units, relying on large amounts of industrially produced agri-inputs, and embedded in stable economic and political conditions (Jia 2021). In contrast to this, agroecological farming systems depend on local bio-physical and climatic conditions, locally generated inputs, farmers' knowledge, and fair marketing mechanisms (Clapp 2021).

1.2.3 National agroecological transitions as multi-level and multi-scale phenomena

Despite its transformative potential, agroecology remains a minor form of production in most countries' agricultural systems. However, a handful of countries – including France, Bhutan, Brazil, Cuba, and Nicaragua – have initiated policy to support the adoption of agroecological farming practices, commonly referred to as an agroecological transition (Duru, Therond, and Fares 2015; Blesh and Wolf 2014; Angeon and Chave 2014; Piraux et al. 2010; Ferguson and Lovell 2014; Sabourin et al. 2018; Le Coq et al. 2020).

National agroecological transitions necessitate interaction and co-creation between many different moving parts and actors in different sectors, i.e. political and administrative; technological and skills support including knowledge creation and diffusion; and input and output market and value chain creation (Anderson et al. 2021). Because agroecology is applied at many different geographic and administrative scales (from farms to territories to whole countries to international value chain arrangements) with various foci (as a set of farming practices, a science, a social movement (Wezel et al. 2009)), supporting agroecological transitions necessitates an understanding of individual elements and their interactions without losing sight of the bigger picture.

In the next section, I give a background on the literature on transitions from the perspectives of the literatures on agroecological transitions and socio-technical sustainability transitions. Then, I explain why socio-technical transitions heuristics can aid in grasping the complexity of agroecological transitions by enabling multifactorial analyses that can move between individual and global issues. I identify gaps in the knowledge on agroecological transitions and socio-technical transitions, such as questions of the socio-psychological factors underlying individuals' behavior and the processes through which change can be effected in agri-food systems, which are addressed by the research questions of the thesis. Finally, I bring together these literatures to form the conceptual framework of the thesis.

1.3 Exploring agroecological and socio-technical sustainability transitions

This section outlines the literature on agroecological transitions and brings it together with the theories of socio-technical sustainability transitions. Gaps in the literature are identified and summarized in section 1.3.3.5. The conceptual framework of the thesis is built from these two bodies of work, and is illustrated at the end of the section.

1.3.1 State of the art: Foci on agroecological transitions

In the past decade, and particularly in the past five years, the literature on agroecological transitions has burgeoned (Anderson et al. 2021). Prior, most agroecologists had not considered transitions in a broad, systematic, multi-level manner and the literature focused on transitions at the farm scale using the efficiency-substitution-redesign model (Ollivier et al. 2018). Broadly, four foci can be discerned in the agroecological literature to understand (aspects of) agroecological transitions. First, the literature on scaling has been mobilized to explore the physical spread of the use of agroecological practices and possible associated policy changes. Second, agroecological principles have been used to design a framework for the conversion of food systems, from the farm to global scales. Third, individuals' agency and social processes have been examined as to their transformative potential in enabling agroecological transitions; this includes issues of gender. Fourth, insights from political sciences and public policy experiments have shown the importance and necessity of a political agroecology.

1.3.1.1 Agroecological transitions as scaling

Recognizing agroecology's multifunctional benefits and potential as a future food system paradigm, researchers and policy-makers converged around the theory and practice of scaling this system as a way to understand and foster agroecology transitions (Anderson et al. 2021). Scaling has three dimensions: it can be seen in terms of geographical spread, in which increasing numbers of families practice agroecology on ever-larger territories ('scaling out'), as a process of vertical integration through the creation of institutions, policies, and laws enabling agroecology ('scaling up'), or through the 'deepening'

of and improvements to the agroecological system itself (Wigboldus et al. 2016; Anderson et al. 2021). All of these dimensions present significant challenges that have been further addressed and experimented with in research and practice in the past decade.

1.3.1.2 Agroecological transitions as conversion of the food system

In 2015 Stephen Gliessman synthesized his previous work on (farm-based) agroecological transitions into a five-level framework for the conversion of food systems to agroecology (Gliessman 2015). This framework has become one of the most commonly used frameworks for understanding agroecological transitions, being used widely by the FAO and many scientists (Anderson et al. 2021). Gliessman's framework begins[3] with increased efficiency on the farm (level 1) and input substitution (level 2), moving to the redesign of the whole farming system based on agroecological principles (level 3) and broader socio-ecological transformation of the food system (level 4), culminating in a deep and wide transformation of policies, institutions, and culture based on social justice and democracy (level 5). Although the first two levels represent incremental improvements that are unlikely to be transformative on their own, level 3 represents a sea change: the possibilities for such a complex redesign of the farming system are deeply shaped by the wider political, economic, social, and cultural context. Hence, even in iconic cases of agroecological transitions[4] the achievement of level 3 changes is difficult and currently relatively rare (Mier Y Terán Giménez Cacho et al. 2018). The dynamics of changes at levels 4 and 5 have been addressed mostly in general terms, without concrete descriptions of the underlying power dynamics (Anderson et al. 2021). Although agri-food transitions to sustainability are deeply cultural processes, closer examinations of the cultural politics (e.g. conflicting values concerning appropriate and desirable types of agriculture) behind these have been underexplored (Meek 2016). Other authors seek to understand food systems change by looking at political and social trends that drive food regimes and food movements, understanding food systems as neoliberal, reformist, progressive, or radical depending on the model of food system embodied in practice and discourse (Holt-Giménez and Shattuck 2011). As such, the frameworks provide an outline of transformative changes, but are missing a clear analytical structure to understand the processes behind the profound changes in agri-food system transformations to sustainability.

1.3.1.3 Individuals in agroecological transitions: Social processes, learning, and gender

Other authors have sought to explain agroecological transitions based on individual actors and social processes that drive change. Bottom-up initiatives, or civil-society led processes of self-organization such as grass-roots social movements, have played central roles in fostering agroecological transitions (Rosset et al. 2011; Khadse et al. 2017; Mier Y Terán Giménez Cacho et al. 2018; Niederle et al. 2020).

[3] The changes between these levels are not seen to unfold successively and neatly - instead, there may be substantial ongoing overlap between them (Anderson et al. 2021).
[4] Iconic cases of agroecological transitions include the national peasant agroecology movement in Cuba, the farmer to farmer movement in Central America, the spread of Zero Budget Natural Farming in India, and the social, political, and institutional changes towards agroecology in Brazil (Mier Y Terán Giménez Cacho et al. 2018; Anderson et al. 2021).

Social processes are particularly important for the construction of agroecological territories beyond the farm level (Rosset et al. 2011; McCune et al. 2016; Bastiaensen et al. 2021). Social processes such as the peasant-to-peasant movement have driven the development of local and international institutions, such as La Via Campesina (Val et al. 2019), which contribute to increasing pressure on governments to create policy and structures supporting transitions to agroecology (Rosset 2014). Building on five years of research across multiple continents, Anderson et al (2021) argue that "a deeply politicized and collectivized practice of building agroecology from the bottom-up is [...] the essential basis for transformation in food systems" (Anderson et al. 2021, 4). Horizontal, peer-to-peer, and experiential learning processes by many different actors are one of the keys to developing strong social processes that support experimentation with agroecology and the co-creation of knowledge (Holt-Giménez 2006; Rosset 2014; Pant 2014; Anderson, Maughan, and Pimbert 2018; Mier Y Terán Giménez Cacho et al. 2018; Francis et al. 2020; Utter et al. 2021).

Addressing gender issues and inequalities is a central principle of agroecology (FAO 2018c). As a key document of global agroecological movements, the 2015 Nyéléni Declaration, states, “women and their knowledge, values, vision and leadership are critical for moving forward. Migration and globalization mean that women’s work is increasing, yet women have far less access to resources than men. All too often, their work is neither recognized nor valued. For agroecology to achieve its full potential, there must be equal distribution of power, tasks, decision-making and remuneration.” (La Via Campesina 2015, 3). Although gender parity is writ large in agroecological thinking, little research has focused on differences between women and men in adopting agroecological farming practices (Akram-Lodhi 2015; Sarrouy Kay, Lemke, and Pimbert 2016). This is particularly surprising considering that issues of gender equity shape access to all components of food systems and are key components of transformations to more resilient food systems (Schipanski et al. 2016). Additionally, research has shown that climate shocks and climatic disasters negatively impact gender equality, particularly in countries in the Global South (Eastin 2018) – implying that farming systems seeking to mitigate the impact of such shocks, such as agroecological systems, may be particularly important to support gender equality. Although authors posit that often, female farmers are the visible or invisible actors involved in adopting agroecological practices (Rosset and Altieri 2017), gender has yet to be systematically integrated in agroecological analyses, as is also the case for related fields such as food sovereignty (Park, White, and Julia 2015). As international peasant organization La Via Campesina itself states, “while gender parity is increasing in La Via Campesina, in many cases it exists more on paper than in practice” (La Via Campesina 2017, 3).

1.3.1.4 Agroecological transitions as public policy

Public policy experiments and experiences across different contexts have been analyzed (Miles, DeLonge, and Carlisle 2017; Gonzalez, Thomas, and Chang 2018; Giraldo and McCune 2019; Murguia Gonzalez et al. 2020; Le Coq et al. 2020) and highlight the importance of a conducive policy environment to further foment transitions to agroecology (Ferguson and Lovell 2014; Pant et al. 2014).

For example, public procurement programs can be used to leverage family farming, as has been shown e.g. in Brazil (Wittman and Blesh 2017; Miranda 2018; Borsatto et al. 2019); future public procurement schemes should focus on promoting agroecological practices (De Schutter 2010). The importance of creating traditional and alternative (e.g. direct farmer-to-consumer schemes such as community supported agriculture) market outlets for agroecological products and value chains to support these is an important factor to ensure the financial viability of agroecological farming (Nigh and González Cabañas 2015; Loconto, Jimenez, and Vandecandelaere 2018). Further, farmers need financial support during the transition from conventional agriculture to agroecology, as yields will drop in the first few years while the soil and environment regenerate (Altieri and Rosset 2007).

The literature on political agroecology emphasizes the historical and current power dynamics at play in processes of agroecological transitions (Anderson et al. 2021; González de Molina et al. 2022). The (just) distribution of socio-economic power and good governance are central aspects of agroecological transitions (Anderson et al. 2021). Political agroecology recognizes that within agri-food systems, the socio-political and ecological are inseparable (Anderson et al. 2021) and aims at fundamentally changing agri-food systems, explicitly linking changes in agricultural practices to changes in food consumption patterns (González de Molina et al. 2022). Considering that almost half of the world's population is over-nourished while almost half is under-nourished (Patel and Philippon 2018), a key question that persists is how governance, control, and power define the choices and agency of actors in the agri-food system (Anderson et al. 2021).

1.3.2 Bringing foci together in multi-level and multi-scale systemic approaches

Recognizing the interlinkages between these foci, recent work on agroecological transitions has taken a more systemic perspective to capture dynamics and interactions between elements driving or hindering transitions, from biophysical factors at the farm scale to national policy. Approaches linking agency and organizational aspects have shown the importance of simultaneous processes involving innovation by both individuals and institutions to enact systemic changes (Blesh and Wolf 2014; Rey et al. 2015). Taking a broader systems perspective, authors have integrated insights from work on scaling agroecology, food systems conversion, social processes and agency, and political agroecology. Figure 2 illustrates how these systemic perspectives relate to the four foci. Cutting across the four identified foci of research on agroecological transitions, six domains have been identified that may individually, but more importantly through their interactions, foster agroecological transitions: rights and access to nature; knowledge and culture; systems of economic exchange; networks; equity; and discourse (Anderson et al. 2019). Eight key drivers lead to change throughout these domains: recognition of the problem itself, which motivates the search for alternatives; effective agroecological practices; social organization; constructivist learning processes; mobilizing discourses; support from external allies; favorable markets; and favorable policies (Mier Y Terán Giménez Cacho et al. 2018).

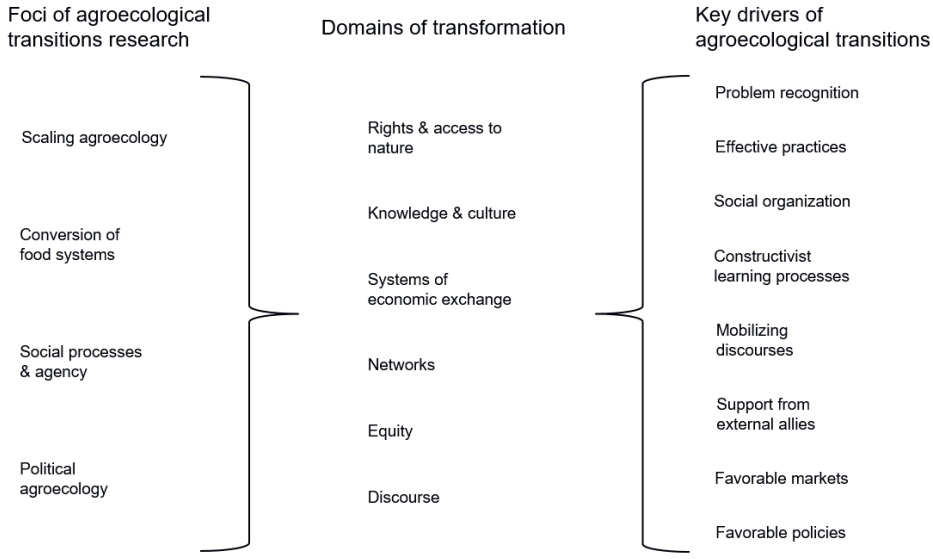


Figure 2: The identified foci of agroecological transitions research in relationship to the domains of transformation and key drivers of agroecological transitions (drawing from Mier Y Terán Giménez Cacho et al. 2018 and Anderson et al. 2019)

In such multi-scale approaches, learning processes and the co-construction of knowledge by many different types of stakeholders throughout the agroecological system (e.g. farmers, farmer advisory services, firms, social movements, government entities and employees, education and research organizations, consumers) are considered to be at the heart of agroecological transitions (Francis et al. 2011; 2013; Chantre and Cardona 2014; Pant 2014; Meek and Tarlau 2016a; David and Bell 2018; McCune and Sánchez 2018; Utter et al. 2021). In their 2019 report, the United Nations' High Level Panel of Experts on Food Security and Nutrition (HLPE)[5] synthesized current knowledge on effecting agroecological transitions, captured in Figure 3 (HLPE 2019a). Their conceptualization captures several points discussed in this and the previous section: the key roles of social movements; the importance of both government and private sector actors in shaping conducive environments; the interconnectivities between all of the different elements; and co-learning processes throughout the system. This last point, however, could be better illustrated in Figure 3 by linking learning also directly to the food producers and consumers themselves, as changes in farm practices and in food consumption directly link to individual and social learning processes.

[5] The HLPE is the United Nations body for assessing the science related to global food security and nutrition. It is the science-policy interface of the Committee on World Food Security (CFS), and at the CFS' request provides independent, comprehensive, and evidence-based analysis and advice concerning food security and nutrition.

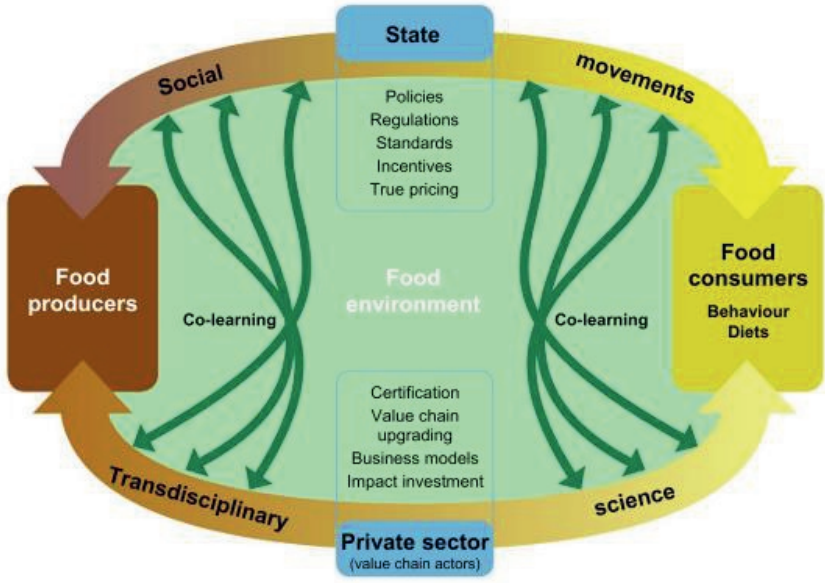


Figure 3: Knowledge, interactions, co-learning, coordination across sectors and by multiple stakeholder groups is pivotal to effecting agroecological transitions (HLPE 2019a, 90)

As can be seen, much is already known about agroecological transitions, but effecting transitions themselves remains difficult. With all of these different moving parts, what is lacking in the literature on agroecological transitions is a structured analytical lens to order the disparate elements and understand their interplays in fomenting change. Such an analytical tool can also help systematize agroecological experiences to enable a better comparison of what drives agroecological transitions across different contexts. In the next sub-section, I explain how the theory of socio-technical sustainability transitions aids in a better understanding of agroecological transitions, and the identification of entry points to foment systemic change, by structuring our understanding of transition dynamics.

1.3.3 Understanding socio-technical sustainability transitions

As the previous section illustrates, because agroecology is so multi-faceted (involving science, practice, social, and political aspects) and agroecological transitions are system-wide, holistic processes, they are difficult to grasp analytically in their entirety, yet in a detailed manner. Looking for a systematic heuristic to be able to explore agroecological transitions from a holistic, yet structured, perspective, that also allowed the identification of specific underlying issues and their interactions, lead from reading

about innovation system approaches in agricultural change (Birner 2012; Klerkx, van Mierlo, and Leeuwis 2012; Darnhofer et al. 2012) to socio-technical sustainability transitions in farming (Darnhofer 2015). This section first explains where socio-technical sustainability transitions thought came from, and what it is, before going into details on two socio-technical analytical lenses - the multi-level perspective and technological innovation systems. Next, I identify gaps in the socio-technical literature, and summarize them in the last sub-section. In the subsequent section, I bring together the agroecological and socio-technical sustainability transitions literatures to form the conceptual framework of the thesis.

In contrast to previously used linear models of innovation, agricultural innovation is now seen as a system-wide, co-evolutionary process that combines technological, institutional, economic, and social change (Klerkx, van Mierlo, and Leeuwis 2012). Interactions between these elements inform how agricultural innovation systems change and evolve. Such "long-term, multi-dimensional and fundamental processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard, Raven, and Truffer 2012, 956) can be conceptualized as socio-technical sustainability transitions.

Socio-technical sustainability transitions theory (STST) provides a framework to organize and understand the dynamics of change and the interactions between systemic elements. By conceptualizing agroecology as the focal technology of a socio-technological system, STST allows a detailed view on the interactions between social and structural elements and processes that shape transitions without losing the larger systemic perspective (Wigboldus et al. 2016). As illustrated in Figure 4, a socio-technical system includes not just elements of agricultural and food production, but also wider social, political, institutional, cultural, and organizational elements. STST provides a structured and holistic heuristic, hitherto underexplored in agroecological literature, for analyzing agroecological transitions. Transitions of agri-food systems are "emergent, non-linear, context-specific, messy processes" (Anderson et al. 2021). STST recognizes that rather than being pre-determined and linear processes, transitions are evolutionary and embedded in social and institutional contexts (Turnheim et al. 2015), and hence may unfold in various (unplanned) ways (Pigford, Hickey, and Klerkx 2018; Plumecocq et al. 2018; Gaitán-Cremaschi et al. 2019). STST posits that, to achieve transitions towards more environmentally sustainable (agricultural) production and consumption, purely technological innovation is not sufficient. Instead, the success of pro-environmental innovations (such as agroecology) depends on their co-evolution with other factors such as market structures, policy measures, and societal preferences. The pace and development of transitions is strongly dependent on local (political, institutional, economic, social) contexts (Wesche et al. 2019), and thus require social, institutional, political, and economic co-innovations by heterogeneous stakeholders (Darnhofer 2015; Duru, Therond, and Fares 2015; Meynard et al. 2017). Processes of change and transitions call into question established practices, and may change long-established resource distribution patterns: there are winners and losers in transition processes, and transitions imply changes in power relations (Grin, Rotmans, and Schot

2011). As such, transitions are deeply contested processes, shaped by many heterogeneous stakeholder groups with different ideas and aims (Geels 2010; Elzen et al. 2011; Geels and Verhees 2011; Raven, Schot, and Berkhout 2012; Marsden 2013; Markard, Geels, and Raven 2020). The literature on just transitions grapples with these questions of contested visions, shifting power relations, and changing resource distribution (Newell and Mulvaney 2013; M. Swilling, Musango, and Wakeford 2016; Jenkins, Sovacool, and McCauley 2018; Mark Swilling 2020; Walk et al. 2021), some with a particular focus on agri-food systems' transitions (Lamine, Darnhofer, and Marsden 2019; Rossi, Bui, and Marsden 2019; Kaljonen et al. 2021).

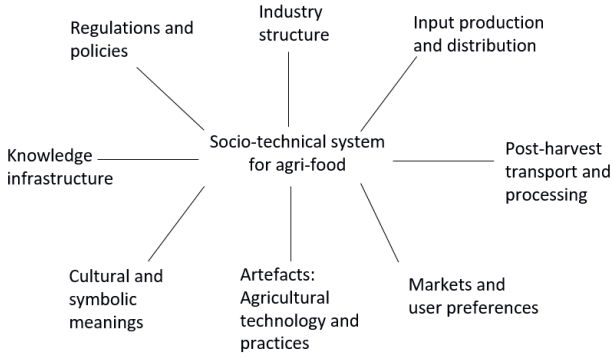


Figure 4: Elements comprising the socio-technical agri-food system (own elaboration based on Geels et al. 2017)

STST allows detailed, yet holistic analyses and a framework that can contribute to the systematization of agroecological experiences across different contexts. As agroecology is a whole-system form of agriculture, the holistic perspective provided by STST is particularly relevant to understanding agroecological transitions. Work by Ollivier et al. (2018) and Anderson et al. (2021) has demonstrated how STS analyses' combined investigation of different aspects aid in deeply understanding detailed processes of agroecological transitions while retaining a 'big picture' view. Because, as explained below, STST provides a structured frame for understanding different elements of transitions, it provides possibilities for generating operationalizable results that may aid in comparing results between different contexts and transferring lessons learned from one area to the next, which has been a problem due to agroecology's focus on local systems. This aids in the identification of entry points which actors, projects, or policies can use to effect change towards agroecology. Although STST research originally focused heavily on energy and transport systems (Köhler et al. 2019) studies on agri-food research have increased in recent years (El Bilali 2018).

1.3.3.1 The multi-level perspective

Of the four strands of thought in STST - the multi-level perspective, technological innovation systems, strategic niche management, and transition management - the former two are more analytically focused theories, while the latter two are more action-research approaches. Because the work for this thesis did not attempt to take an action-research approach due to structural and political constraints, I focused on the former two as bases for the analysis of Nicaragua's agroecological transition.

In the multi-level perspective on sustainability transitions (MLP), one of the main strands of STST which has been applied to agroecological transitions (e.g. (Isgren and Ness 2017; Cerdan et al. 2019; Anderson et al. 2021; Bui 2021; Polita and Madureira 2021), transitions are conceptualized as changes to a dominant 'regime' - the entrenched 'rules of the game' that account for the stability of existing systems (Geels and Schot 2007; Geels, Hekkert, and Jacobsson 2008). Regimes encompass networks of actors and social groups, the formal and informal rules used to maintain the dominant system, and related technical and material elements (Geels 2004; 2011). Regimes are pressured to change due to e.g. events or crises, such as climate or world market shocks, that occur in the 'landscape' level, and/or by innovations or counter-movements that provide a better way of solving a societal problem (Geels 2002). Such new innovations are seen to emerge from 'niches', which form when stakeholders come together around a novelty, experiment with the novelty and, in the best case, develop processes that induce its scaling up and out, thereby causing pressure on the regime to change (Geels 2002). The 'landscape' level represents contextual factors outside of the daily reach of stakeholders, including e.g. cultural dynamics that change only slowly and incisive events such as mentioned above (Geels 2002). Interactions between the three levels drive and shape how socio-technical systems change over time (Geels 2002).

Landscape factors that have had strong effects on agri-food systems include climate change, shifting societal values (e.g. around animal welfare or the negative impacts of industrialized food systems), macro-economic events (e.g. the 2007/2008 financial crisis), and the consolidation of power by corporate food system actors over the past decades (Anderson et al. 2021). Food regime theory can be helpful to shed light on the landscape-level global and historic antecedents and political ecological basis that form the basis of today's dominant global food regime (Anderson et al. 2021). Centered, in the global context, on contradictions and political struggles between different social groups in relation to food and agriculture, food regime theory has identified two historical food regimes that have evolved into the current 'corporate food regime' in which power has shifted from the nation-state to the global power of corporations (McMichael 2009). The current globally dominant corporate food regime is characterized by a productivist mentality that emphasizes monocultural, high-input, energy intensive agriculture, aiming to standardize all aspects of food systems in order to enable industrialization, decrease costs of production, and increase profits (Holt-Giménez and Shattuck 2011; McMichael 2013; K. Jansen 2015; De Schutter 2017; Anderson et al. 2021; Conti, Zanello, and Hall 2021; Leeuwis, Boogaard, and Atta-Krah 2021).

1.3.3.2 Technological innovation systems

Niches represent the emergence of radical socio-technical alternatives to the dominant principles of the regime (Anderson et al. 2021). In the MLP, niches are considered to be based on a central, innovative technology[6] around which actors come together in co-learning and co-creation processes, aiming to promote the innovation. As such, niches are spaces that bring together technological and social processes. This is particularly pertinent for agroecology, which as explained above also integrates both technological and social elements. Building on the innovation systems literature, niches are seen to be formed by actors, their networks, the infrastructures and institutions, and their interactions in doing so as they develop in support of the central technology (Wieczorek and Hekkert 2012). The extent to which these niche structures work to advance the innovation is captured by the notion of 'technological innovation systems' (TIS). TIS analyses document the work performed by actors, infrastructures, institutions, and their interactions, according to how well they perform a set of seven (or eight) functions in support of the innovation (Hekkert et al. 2007; Bergek et al. 2008; Bergek, Jacobsson, and Sandén 2008). These functions are knowledge development concerning the innovation, diffusion of this new knowledge, resource mobilization, entrepreneurial experimentation with the innovation, market formation for new products, guidance of the search (i.e., the formulation of goals for the innovation, based on heterogeneous actors' expectations, articulated user demand, and societal discourse), and the creation of legitimacy concerning the innovation throughout broader society (Hekkert et al. 2007; Bergek et al. 2008). Each system function can be fulfilled in various ways, and which characteristics are important depends on the stage of the niche's development: whether it is in an early, formative stage, or at a later growth stage (Bergek et al. 2008; Suurs et al. 2010). Understanding how a TIS' functions are being fulfilled (or not) can provide strategic insights for practitioners and policy-makers that seek to support the niche's development (Suurs et al. 2010).

In sum, the goal of enacting these functions is to pressure the regime to change according to the niche's needs, with the hope of eventually replacing it (Rosenbloom, Berton, and Meadowcroft 2016). The question of how niches manage to link themselves to regime elements in order to effect this change is a key question in STST research, as these processes lead to the integration of new rules and practices within the regime that may further foment more profound regime reconfigurations (Bui et al. 2016). The notion of 'anchoring' has been used to describe how niches link into the regime, with three different forms of anchoring (through the technology itself, through networks, through institutions) originally identified (Elzen, Van Mierlo, and Leeuwis 2012). Another way of anchoring is through social discourse and the construction of shared visions, which can later be anchored in local policies and public action

[6] The concept of 'technology' has (at least) two meanings. First, it refers to material and immaterial knowledge, including both hardware (e.g. tools, machine, products) and software (e.g. digital protocols, but also procedures and processes), that can be used to solve real-world problems. Second, it refers to technical knowledge, which can be either general or embodied in the physical artefact. Following other authors, I use 'technology' as inclusive of both of these meanings, i.e. as both physical artefact and knowledge (Layton 1974; Das and Van de Ven 2000; Bergek et al. 2008).

(Bui et al. 2016; Rosenbloom, Berton, and Meadowcroft 2016). These processes of anchoring, while discussed in the literature, remain to be more deeply investigated and theorized.

Beyond the two analytical frameworks discussed here, the subsequent sub-sections hone in on issues that remain underexplored in the STST literature. Gaps in our knowledge that are addressed by the thesis are articulated in the final sub-section.

1.3.3.3 Actors and agency

While the agency of individual actors inside the niche was first neglected in STST research, more recent work has focused on untangling individual's roles and agency, and the interactions between agency and more structural considerations, in transitions processes (Kern 2015; Pesch 2015; Fischer and Newig 2016; Avelino 2017; Hassink, Grin, and Hulsink 2018; Upham et al. 2018; Bhamidipati, Hansen, and Haselip 2019; Duygan, Stauffacher, and Meylan 2019; Geels 2020; Huttunen et al. 2021). Much work has focused on how individuals enact power in transitions (Avelino and Rotmans 2009; Avelino and Wittmayer 2016; Ahlborg 2017; Avelino 2017; Katre and Tozzi 2019; Rossi, Bui, and Marsden 2019; Sovacool and Brisbois 2019; Scherrer, Plötz, and Van Laerhoven 2020; Avelino 2021; Braunger and Walk 2022). Interestingly, although issues concerning gender, and particularly gender and power, percolate throughout transition processes, scant attention has been paid to this in the literature (Kronsell 2013; Walk et al. 2021; Braunger and Walk 2022). Considering that individuals are the ultimate enactors of transition processes, authors have called for STST to engage with the behavioral bases of transitions and focus on how individuals engage in processes of social change (Upham, Bögel, and Dütschke 2019; Ruhrort and Allert 2021). Particularly research on consumers and the social acceptance of new technologies has used insights from social psychology (Bögel and Upham 2018; Bögel et al. 2018). Such research is promising because psychology specializes in deeply exploring the mechanisms or processes through which social phenomena inform individuals' behavior (Upham, Bögel, and Johansen 2019). Such insights could aid e.g. policy-makers or firms in better pre-emptively accounting for, and harnessing, individuals' behavior and their agency in transition processes. The integration of insights, theory, and concepts from psychology and social psychology into STST frameworks remains a promising, but hitherto underexplored, avenue of research (Bögel and Upham 2018; Upham et al. 2018; Bögel, Upham, and Castro 2019; Upham, Bögel, and Johansen 2019; Martiskainen and Sovacool 2021; Ruhrort and Allert 2021).

1.3.3.4 Transitions in the Global South

The field of STST was originally conceived in northern Europe, and its main frameworks, including MLP and TIS, were conceptually developed and first empirically tested in Global North contexts. In recent years, empirical data and analyses of transitions happening in Global South contexts have increased rapidly, but still remain underrepresented in the transitions literature. Authors writing on transitions in the Global South have urged for a more nuanced consideration of factors such as informal economies (Ramos-Mejía, Franco-Garcia, and Jauregui-Becker 2018), the existence of 'splintered'

regimes in which one societal need is met by a plethora of different options (van Welie et al. 2018; Wieczorek 2018) and the inclusion of diverse, non-Western epistemologies into transitions research and practice (Ghosh et al. 2021). Many authors writing on transitions in the Global South agree that STST frameworks, though useful tools for transitions analyses in richer as in poorer countries, need to be amended to take into account differences that may exist in the socio-economic framework conditions and may impact niche development (Edsand 2016; U. E. Hansen et al. 2018), such as technological (e.g. limited capacities and knowledge of personnel, limited adoption capacity), financial (e.g. lack of access to financing and insufficient mechanisms for support), and institutional (e.g. uncertain policy landscape and weak infrastructure) barriers (Suzuki 2015; Wieczorek 2018).

1.3.3.5 Gaps in the literature

As detailed in sections 1.3.1 and 1.3.2, a structured analytical lens to order and systematize agroecological transitions is lacking; STST provides such a tool. As explained in section 1.3.3, while knowledge in STST has developed rapidly in the past decades, five areas that remain underexplored emerged from the literature review: 1) how niches link to regimes while attempting to effect change within regimes; 2) socio-psychological aspects that shape individuals' behaviors in sustainability transitions; 3) issues of gender in sustainability transitions; 4) transitions taking place in countries in the Global South; 5) agri-food systems transitions. The thesis brings together the literatures on agroecological transitions and STST to address these five gaps, as further explained in sections 1.4 and 1.6.

1.4 Conceptualizing agroecological transitions as socio-technical sustainability transitions

Bringing together these two bodies of scientific literature - agroecological transitions and socio-technical sustainability transitions - the conceptual framework of this thesis uses a multi-level lens to understand agroecological transitions (Figure 5). Like transitions in the Global South, transitions to sustainable agri-food systems were initially not a focus of the STST literature; this has changed in the past five years with a burgeoning literature on different aspects of transitions to sustainable agri-food systems. Building on this literature and the agroecological literature, the thesis follows the framework shown in Figure 5.

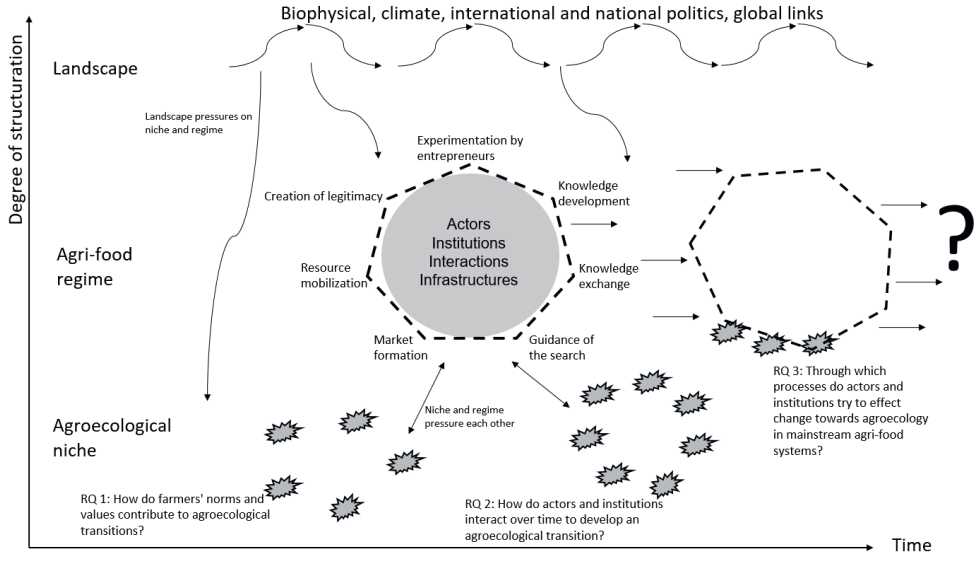


Figure 5: A multi-level perspective of an idealized agroecological transition (own elaboration based on Geels 2002) with the research questions (RQ) situated within the framework (see section 1.6 for more details on the research questions)

In the idealized scenario presented in Figure 5, the regime is a national agricultural system, characterized by conventional, high-external-input agriculture, as described in section 1.2. Information on agroecological practices and principles is gathered locally or enters from an outside source (U. E. Hansen and Nygaard 2013; Wieczorek, Raven, and Berkhout 2015; Binz and Truffer 2017; Fuenfschilling and Binz 2018; Wieczorek 2018; Bhamidipati, Hansen, and Haselip 2019; Boillat, Belmin, and Bottazzi 2021). Landscape events - e.g. ongoing climate change due to global warming; a severe climate shock, such as a Category 5 hurricane; falling world market prices for export crops - precipitate the pressure on farmers to move towards resilient, productive forms of agriculture (Anderson et al. 2021). In the sustainability transitions literature on agri-food transitions, alternative agri-food movements are often conceptualized as niches (Bui et al. 2016; von Oelreich and Milestad 2016). Agroecology begins as to be practiced as a niche innovation, with farmers, facilitators, or grassroots political activists experimenting with ways of implementing agroecology locally and according to their needs (Holt-Giménez 2006; Bergez, Audoin, and Therond 2019; Magrini et al. 2019; Polita and Madureira 2021; Rossing et al. 2020). Agroecology continues to spread in co-innovative and co-created processes by heterogeneous actors - farmers decide to adopt agroecological practices on their farms and farmers' organizations begin to scale agroecology horizontally, over large areas; agroecological input and product market infrastructures are created; agroecological knowledge is formalized and taught through farmer extension and advisory services as well as at universities (Gonzálvez, Salmerón, and Zamora 2015; Henderson and Casey 2015; McCune et al. 2016; Khadse et al. 2017; Loconto et al. 2018;

McCune and Sánchez 2018; Mier Y Terán Giménez Cacho et al. 2018; Utter et al. 2021). Institutional, bio-physical, and individual socio-psychological considerations shape actors' decision-making to engage with agroecology (Blesh and Wolf 2014), including issues such as gender (Sarrouy Kay, Lemke, and Pimbert 2016). Civil society, social movements, and consumer organizations play crucial roles in raising the political dimensions of agroecology, particularly through demonstrating alternative agri-food models and emphasizing the need for deeper systemic changes (Holt-Giménez and Shattuck 2011; Rosset 2014; Wezel et al. 2020). Actors and networks from the agroecological niche begin to link with regime actors and into regime structures; for example, local and then national policy and planning initiatives can begin to include agroecology. At the same time, the agroecological niche competes with other alternative food niches (e.g. organic agriculture) that may be more aligned to and supported by the dominant regime (Anderson et al. 2021). As the regime begins to change due to pressure from the agroecological niche, four things can occur. First, the regime can transform itself - it modifies the direction of its development paths and innovation activities according to agroecological principles (Geels and Schot 2007). Second, it can undergo a process of de-alignment and re-alignment (in which the regime erodes due to a large and sudden shock at the landscape level; after a period of struggle between multiple niches, e.g. organic agriculture, agroecology, and climate-smart agriculture, one of these becomes dominant and forms the core for the re-alignment of a new regime) (Geels et al. 2016). Third, if sufficient landscape pressure occurs simultaneously with sufficient niche development, the niche can break through and replace the existing regime (Geels et al. 2016). Fourth, the regime can reconfigure its basic architecture to accommodate symbiotic innovations developed in niches; these innovations are initially adopted by the regime to solve local problems but subsequently trigger deeper and wider regime change (Geels and Kemp 2007).

As Anderson et al (2021) stress, agroecological transitions are *processes* that may occur over large time-periods, with many different actors involved across many scales and levels, and are constantly evolving without a fixed end point. Bridging the literatures on agroecology and socio-technical sustainability transitions, the thesis explores the agroecological transition in Nicaragua at three different moments and levels, as illustrated in Figure 5 and further explained in section 1.6 below. The loci of the three research questions in the conceptual framework arise from a bridging of the state of the arts of these two literatures. The question of socio-psychological aspects informing actors' behavior is underexplored in both the sustainability transitions and agroecology literatures (research question 1). While the agroecological literature stresses social and political processes that enable transitions, a structured format for understanding, analytically organizing, and drawing conclusions that point to entry points for changes in policy and practice is missing. STST provides such a framework and allows a detailed analysis of who does what in support of an agroecological transition (research question 2). Likewise, while the agroecological literature features multiple ways of understanding change in agri-food regimes, the processes through which such change happens remains poorly understood. Here, the STST literature offers an explanatory model of how agroecological actors can link into the dominant agri-food regime

to effect change (research question 3). The research questions are further expounded upon in section 1.6.

1.5 Intended contributions of the thesis

This thesis aims to contribute to the recent discussion of agroecological transitions in the literature and addresses the interest in, and need for, systems approaches for understanding agroecological transitions. It uses a socio-technical sustainability transitions perspective to explore the dynamics of a national transition from conventional (fossil-fuel-input-based) agriculture to agroecology, which utilizes ecological principles for the design and management of resilient, sustainable, productive, and socially just agri-food systems. Although the literature recognizes the complexity of agroecological transitions, which involve many different stakeholders and factors at many different levels in and parts of the agri-food system, there is a lack of systematized, systemic approaches taking into account the broader agri-food innovation system and offering more easily operationalizable results. In an effort to address these gaps, this thesis:

1) Documents and explores the dynamics of a national agroecological transition that has been unfolding for the past four decades and continues to develop;

2) Frames agroecological transitions as socio-technical sustainability transitions;

3) Investigates how the agroecological transition is unfolding at three different loci of the agri-food system using the case study of Nicaragua

- at the micro-level of individuals inside the niche;
- at the micro-meso level of individuals and organizations inside the niche;
- at the micro-meso level interacting with the macro level, at the niche-regime border; and

4) Teases out generalizable enabling or limiting factors that contribute to or hinder the development of agroecological transitions.

The thesis aims to go beyond the existing applications of socio-technical sustainability transitions theory to agroecological transitions through its in-depth case study of Nicaragua and on its focus on processes happening inside the agroecological niche and at the niche-regime interface in Nicaragua. It addresses six gaps in the socio-technical sustainability transitions and agroecological literatures, as noted in section 1.3.3.5 (chapters in which these gaps are addressed are italicized):

- Although the sub-field of socio-technical transitions happening in the Global South has grown in recent years, there is still a lack of empirical data and analyses, especially concerning detailed studies at a national level, on transitions in the Global South (*whole thesis*).

- The same is true of the literature on socio-technical transitions to sustainable agri-food systems *(whole thesis).*
- While the agroecological literature offers a wealth of empirical data on transitions to sustainable agri-food systems, a systematic framework for organizing and analyzing this data that allows the drawing of lessons supporting policy-making and practice and the comparison of transition processes across different contexts is lacking *(whole thesis).*
- Both the agroecology and socio-technical transitions literatures are weak in conceptualizations of individual behavior based on social psychological approaches; little attention has been paid to gender issues *(Chapter 3*).
- Particularly systematic TIS analyses of transition processes in the Global South are lacking in the socio-technical literature *(Chapter 4).*
- The processes through which niches link to regimes in their attempts to effect regime change are poorly understood in the socio-technical literature *(Chapter 5).*

The thesis is unique in five aspects. First, a systematic description and analysis of the agroecological transition in Nicaragua has not yet been undertaken. Chapter 2 documents Nicaragua's agroecological transition, including its roots, and provides the groundwork for the following three empirical chapters. Second, the three different studies comprising the empirical work on the development of the agroecological transition in Nicaragua (Chapters 3, 4, and 5) are located at different geographic and administrative levels of the country, and conceptually zoom out from farm to national level. Third, this dissertation is unique in its bridging of the agroecological and socio-technical sustainability transitions literatures. Bridging between agroecological and socio-technical sustainability transitions theory is expected to be particularly fruitful for better understanding agroecological transitions as both are holistic, systemic disciplines. Fourth, this dissertation is unique in its application of socio-technical sustainability transitions theory to understand a national agroecological transition at three different loci in the agri-food system: on the farm; inside the forming agroecological 'niche' within the national agri-food system; and looking at the niche-regime interface to understand how the niche links to the regime to effect changes within the national agri-food system itself. The implications of the combined results from these three analyses, and their synthesis, is discussed in the synthesis in Chapter 6. This goes beyond the existing literature on socio-technical sustainability transitions analysis applied to agroecological transitions.

This dissertation's scientific relevance is that it examines the implementation of agroecological transitions by applying a socio-technical sustainability transitions lens, thus bridging recent scholarly innovations on agroecological transitions and sustainability transitions. For the agroecological literature, the dissertation contributes a case study of the still-new use of socio-technical sustainability transitions theory to understand ongoing agroecological transitions. For the socio-technical systems literature, the

dissertation contributes empirical evidence to the underdeveloped, but rapidly growing, body of work on sustainability transitions in agri-food systems. It further contributes to the burgeoning, but still undersized, literature on sustainability transitions in the Global South.

1.6 Overall research objectives and specific research questions

Based on the gaps identified in section 1.5 and the intended contributions to the literature, the overall objective of this thesis is to unpack an agroecological transition in-the-making and understand how this process has played out at different loci in Nicaragua's agri-food system. To do so, this thesis follows both an exploratory and an explanatory approach. Because, as outlined in section 1.3 above, the socio-technical literature is weak concerning empirical research on agroecological transitions, and even less on this in Global South contexts, the thesis both explores (documents) and explains (analyzes) the unfolding of the agroecological transition in Nicaragua. In other words, the objective of the thesis is to document and analyze Nicaragua's agroecological transition, specifically the involved processes, institutions, and stakeholders and their interactions.

Following this objective, the overarching research question asks: How do interactions between processes, institutions, and stakeholders produce and shape the agroecological transition, and which factors enable or limit the development of the agroecological transition? Based on this and the gaps in the literature identified above in section 1.3, three sub-research questions were derived, each addressing a different location within the conceptual framework, as illustrated in Figure 5. These sub-research questions guided the different studies portrayed in Chapters 3, 4, and 5 (loci within conceptual framework and chapter numbers italicized):

> RQ 1. How do personal norms and gender influence farmers' adoption of agroecological practices? *(Micro level of individuals' behavior, Chapter 3)*
>
> RQ 2. How do actors, networks, infrastructures, and institutions interact over time to develop an agroecological transition? *(Micro-meso level of agency and systemic development, Chapter 4)*
>
> RQ 3. Through which processes do actors and institutions try to link into the regime to effect change towards agroecology in mainstream agri-food systems? *(Meso-macro systems analysis, Chapter 5)*

Each empirical chapter answers one research question using the exploratory and explanatory approach described above. The research questions are embedded in the socio-technical framework on agroecological transitions presented in section 1.4; Figure 5 illustrates the loci of the research questions within the conceptual framework. Methods for data analysis used to answer each research question are detailed in section 1.7.5.

1.7 Description of research design and main methods used for data collection and analysis

This section describes the overall research design of the thesis, elaborating on data collection and analysis methods. Each of the empirical chapters provides specific and much greater detail on the research methods, data collection, and data analysis methods used.

1.7.1 Study context: Nicaragua

The empirical data on which this dissertation is based comes from Nicaragua, the Central American country that has been at the vanguard of agroecology since the 1980s. As a country in the tropics (the global zone with the highest biodiversity, largest potential bioproductivity, and already heavily impacted by climate change), the use of productive, resilient, adaptive farm management methods, including agroecology, is central to ensure long-term agronomic viability (Gourdji et al. 2014; Godfray et al. 2012; Chappell et al. 2013). According to the IAASTD, Central America, and specifically regional bean and maize production, will be particularly heavily impacted by climate change events, including droughts, floods, and climate shocks such as powerful tropical storms (IAASTD 2009). The effects of climate change, such as the twin problems of 'too little' and 'too much' water (delayed rains and drought, with subsequent storms eroding away the parched earth, as well as increasingly extreme storms), have hit Nicaragua hard. In 2014, in what was thought to be the worst drought in Nicaragua in 44 years, a four-month delay in rain affected an estimated 100,000 farmers in two-thirds of the country's municipalities; when the rain did come, it was with such intensity that the government announced a state of emergency to cope with nationwide flash floods (Guardian 2015). In the span of two weeks in 2020, Nicaragua was hit with category 4 hurricane Eta, followed by category 5 hurricane Iota just 13 days later. Unprecedented in 170 years of meteorological data, both hurricanes touched land within 25 kilometers of each other in northeastern Nicaragua (Cappucci 2020). Clearly, the building of resilient, adaptive, and productive agro-ecosystems is paramount to sustaining national agricultural production, particularly among staple crops such as maize and beans.

Besides experiencing a bio-physical urgency for sustainable agricultural systems, Nicaragua has been at the vanguard of agroecology in practice, science, social movements, and politically, for four decades (Gonzálvez, Salmerón, and Zamora 2015). Since the 1980s, the farmer-to-farmer methodology has been used to spread agroecology throughout the country, with the largest association of medium and small farmers stating in 2013 that one third of their 60,000 participants had used some form of agroecological practices (Herrera 2014). Scientifically, Nicaragua may be considered a regional and global 'lighthouse' of agroecology, with knowledge creation and dissemination occurring by many stakeholders, including through farmer cooperatives, women's organizations, national universities and technical education

programs, local and national government initiatives, local civil society organizations (CSOs) and international non-governmental organizations (NGOs),[7] and regional initiatives (Salazar Centeno 2013). Key moments in the global development of agroecology have occurred in Nicaragua over the past forty years, such as the 'Managua Declaration' that laid the groundwork for the founding of international peasant organization La Via Campesina (La Via Campesina 1992). In 2007, the government passed policy supporting agroecological farming; policy supporting the tightly related subject of food and nutritional sovereignty and security was passed in 2009 (Godek 2015). Hence, documenting and unpacking this on-going, four-decade long process, which was and is fundamentally important to the global development of agroecology, forms the basis of Chapter 2 and is the starting point of this thesis.

1.7.2 Description of case study

A single case-study research design was selected as appropriate for providing in-depth insights into the dynamics of transition processes (following Flyvberg 2006; Yin 2003). The case study method was selected because it provides in-depth insights into complex social processes and phenomena, it allows for the holistic capturing of rich data from a variety of sources that permits the triangulation of research results, and it makes possible the meaningful characterization of these processes and phenomena (Yin 2014).

The geographic unit of analysis for this research is the country of Nicaragua. Conceptually, the unit of analysis is Nicaragua's agri-food system. Temporally, the research focused on the period from the 1980s to 2018. The time period is fixed until 2018 because of the lasting effects of 2018's popular uprising, in response to which the government has severely curtailed civil liberties in the country.

The study was conducted on the ground in Nicaragua in two phases: a first phase in September and October 2014 and the second phase between January 2016 and March 2018. While the first phase served as an introduction to agroecology in Nicaragua, I lived and worked in Nicaragua during the second phase, which allowed a much richer perspective on socio-political issues hindering the government's many good policy initiatives from being realized. Through my job at the International Center for Tropical Agriculture (CIAT) I was able to work among organizations promoting agroecology in Managua and around the country. I connected with people engaged in a broad range of (often peripherally agroecological) activities (farmers, representatives of farmer organizations, representatives of women's organizations, university professors and students, researchers, NGO staff, government administrators at national and municipal levels, private sector entrepreneurs), observed dynamics as the agroecological sector developed, and took part in workshops, conferences, meetings, and other events with various stakeholder groups (farmer organizations, women's organizations, international research

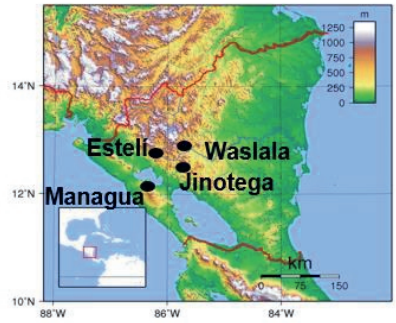
[7] Following usage in Nicaragua and Obuch (2014), I differentiate between international non-governmental organizations and national civil society organizations.

organizations, national CSOs, and international NGOs). Hence, many informal interactions and other meetings and events not listed in this section enriched the analysis offered by this dissertation.

1.7.3 Selection of research areas and respondents

This dissertation is based on a case study of agroecology in Nicaragua. The research area was chosen due to its high vulnerability to the impacts of climate change, and the resulting necessity of creating productive and resilient agro-ecosystems. Further, with its forty years and counting of agroecological experience, Nicaragua offers an interesting and informative case study to learn from and guide other peoples and nations wanting to implement agroecological transitions.

Geographically, data collection occurred around several areas in northern and central Nicaragua. Many organizations and activities were and are based in Managua, the national capital. Three areas (around the municipalities of Estelí and Waslala) were selected for research with farmers. These areas were selected because they have similar socio-political contexts (small farms growing staple crops of corn and beans) but different biophysical settings. Estelí is in the Dry Corridor of Central America, an area that stretches from southern Mexico to Panama, whereas Waslala is in the humid tropics. Informally, I attended meetings and visited farmers' fields around Jinotega, capital of the department of Jinotega, also in the Dry Corridor, and in Nicaragua's coffee heartland. My participation at such events in all of the locales served to give me a much richer picture of the unspoken details and behind-the-scenes workings of individuals and institutions in the agroecological transition. Hence, Jinotega is included in the map of study locations in Figure 6, which illustrates the locations of the research areas in Nicaragua, and details the data collection methods that were used at each research locale. The selection of respondents at each research locale varied according the research question being addressed and the methods being used; details are given in Chapters 3, 4, and 5.



Method	Managua	Estelí	Waslala	Jinotega
Semi-structured interviews	x	x	x	
Semi-structured interviews and farm visits		x	x	
Survey		x		
Workshops		x		
Participation at meetings, farmer field events, conferences	x	x	x	x

Figure 6: Map of field study locations in Nicaragua (mapsof.net 2014) and data collection methods used at each locale

1.7.4 Data collection methods

Field research, including the survey, interviews, and workshops, was carried out in 2014 and 2016-2018 in Nicaragua. A review of scientific literature, grey literature, newspaper articles and other media was ongoing before, during, and after the research, whether I was in Nicaragua or not.

A mixed methods approach combining qualitative and quantitative methods was used to gather and analyze data. A mixed methods approach was chosen because it gives the possibility of triangulating data from a variety of different sources (Yin 2014). Table 1 summarizes the data collection methods, participants in the different research methods, and each methods' contribution to the research questions. Further information that contributed indirectly to this dissertation was gathered during my participation at farmer field days and farm visits, tours of producer organizations' production sites, workshops, meetings, and conferences with national CSOs and universities, international NGOs, and governmental institutions. Data was collected in Spanish, in which I became proficient to a high level.

Table 1: Summary of data collection methods, details of research participants, and contribution of each method to answering the research questions (RQs)

Type of data gathering	Details of respondents (and organizations, if applicable)	RQ1	RQ2	RQ3
Semi-structured interviews	4 scientists and extension agents from producer organizations 6 scientists from research and education institutes 2 department managers from government institutions 2 managers from financial institutions 1 scientist from an NGO 3 scientists from CSOs		X	X
Farm visits and semi-structured interviews	9 agroecological smallholders (3 female, 6 male)	X	X	X
Survey	119 smallholder farmers (69 female, 50 male)	X		
Workshops	2 with agroecological smallholders, total: 27 participants (11 female, 16 male) 1 multi-stakeholder, with 8 participants from 6 organizations		X	X
Literature review	Scientific literature Grey literature from involved organizations Newspaper articles, videos from news organizations, social media		X	X
Document analysis	Government policies Internal documents from involved organizations		X	X

Qualitative methods for data collection used were participant observation, workshops, and interviews, which are apt in agroecological research (Putnam et al. 2014; Bacon, Mendez, and Brown 2005; Wittmayer et al. 2014; Wezel et al. 2015; Guzmán et al. 2012; C. MacDonald 2012). A key methodological tool used is an innovation history timeline (Douthwaite and Ashby 2005). To understand which actors contributed what to key events in the development of agroecology, the innovation history timeline was co-created and co-analyzed in three workshops with stakeholders representing different groups, functioning as a boundary object (Klerkx et al. 2012). A quantitative method (a survey of farmers' agroecological practices and personal norms) added statistical information concerning the farm-level adoption of agroecology (detailed in Chapter 3). A thorough review of relevant scientific and grey literature preceded, accompanied, and post-dated the case study. Data analysis methods, chosen according to research questions and the desired information, are outlined in greater detail in the next paragraph. Table 2 provides an overview of the data needed, stakeholders targeted, data gathering methods, and data analysis methods used to address each research question.

Table 2: Data and methods used to address each research question

Research question	**RQ1**	**RQ2**	**RQ3**
Analytical method	Regression analysis with SPSS	Analysis of structures and functions of the agroecological TIS at key events on the innovation history timeline	Analysis of regime-TIS interactions, following Elzen et al (2012) and Geels and Schot (2007)
Scientific field of analytical method	Social psychology (values, beliefs and norms)	Technological Innovation Systems analysis (TIS, subset of STST)	Multi-Level Perspective (MLP, subset of STST), anchoring framework
Data obtained	Survey of 120 (non) agroecological farmers	• Information on organizations, actors, infrastructures, networks, and activities involved in the development of agroecology in Nicaragua • Innovation history timeline of development of agroecology in Nicaragua	Information on which elements of agroecology have been integrated into regime and through which processes
Stakeholders targeted for data collection	Smallholder farmers involved in farmers' organizations in Estelí	Actors from many different stakeholder groups: government, farmers, research, universities, women's organizations, local CSOs, international NGOs and development projects, financial organizations	Actors from many different stakeholder groups: government, farmers, research, universities, women's organizations, local CSOs, international NGOs and development projects, financial organizations
Data-gathering method	• Behavioral survey: adoption of agroecological	• Key stakeholder interviews • Workshops with farmers	• Results from RQ 1+2 • Literature and document review

Research question	RQ1	RQ2	RQ3
	practices and behavioral drivers of adoption of practices • Follow-up interviews	• Workshops with organizational actors • Co-creation and co-analysis of innovation history timeline and key events with multiple stakeholder groups	• Follow-up interviews with key stakeholders

1.7.5 Data analysis methods

Data analysis was based on the different requirements of each research question, data set, and collection method (see Table 2). To answer research question 1, statistical analysis was performed on the data set created from a survey of 120 farmers (see Chapter 3 for more information). To answer research question 2, an innovation history timeline of agroecology in Nicaragua from 2007 (since when agroecology can be said to be in an accelerated phase) to 2018 was analyzed using structural-functional technological innovation systems analysis (TIS; see Chapter 4 for details). To answer research question 3, the innovation history timeline was expanded to the last forty years of agroecology in Nicaragua, and analyzed to explore through what methods and to what extent agroecology has managed to change the dominant agricultural regime (Chapter 5 explains this in greater detail).

1.8 What follows: Outline of the thesis

The thesis is an exploration of the Nicaraguan agroecological transition between the 1980s and 2018. Following this introduction, an in-depth background chapter provides context on different facets of agroecology and agroecological transitions and on Nicaragua's (agrarian) political economy since the 1950s (because past developments set the stage for the emergence and rapid spread of agroecology). This is followed by three empirical chapters that each examine the agroecological transition at a different moment and space within the framework, as shown in Figure 5. Using a socio-technical system perspective, the three empirical chapters (Chapters 3, 4, and 5) explore the agroecological transition in Nicaragua at the three moments marked in grey in Figure 5. Each chapter is further explained below. Concluding the thesis, a final synthesis chapter zooms out to take a holistic perspective and synthesizes the issues that are addressed in this introductory chapter and further discussed in the context chapters.

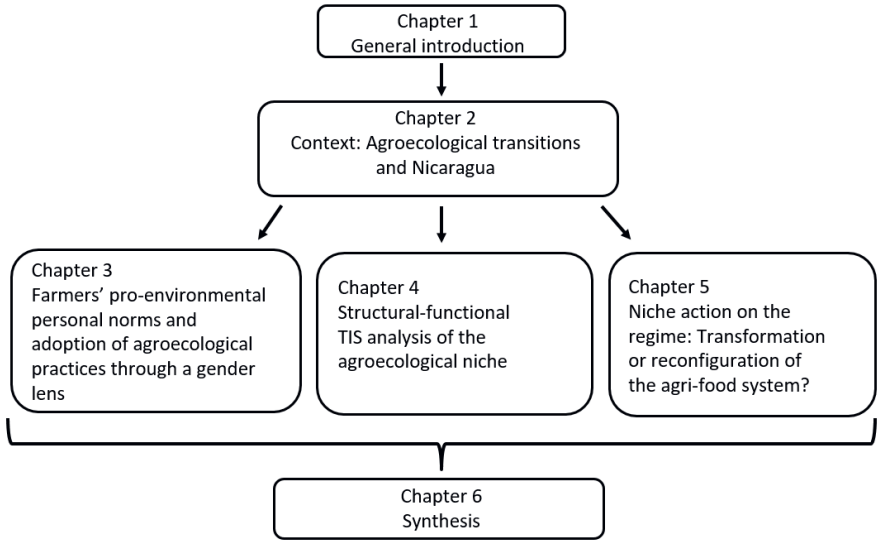


Figure 7: Overview of the thesis

Figure 7 illustrates how the chapters fit together conceptually. Chapter 2, which goes in-depth to paint the unique Nicaraguan context that enabled it to become an early leader in agroecology, provides the context for the three empirical chapters. The empirical chapters follow the research questions - Chapter 3 answers RQ 1, Chapter 4 answers RQ2, Chapter 5 answers RQ3. As Figure 5, found above in section 1.4, illustrates, from a socio-technical sustainability transitions perspective, the empirical chapters zoom out from the level of the individual actor and farm (Chapter 3) to understand what is happening inside the agroecological niche as it grows (Chapter 4) to the border between the niche and regime, asking how the niche is impacting on the regime (Chapter 5). The context and empirical chapters are bookended by a general introduction and a concluding synthesis.

Chapter 2 provides contextual information on the history of agroecology in Nicaragua. A vanguard of agroecology since the 1980s, Nicaragua has played a key role in the global development of agroecological thought, practice, movements, and policy. For example, 1992's Managua meeting, and the ensuing Managua Declaration, were crucial in the formation of global peasant organization La Via Campesina and the development of its theoretical base; the farmer-to-farmer pedagogical model that forms the basis of the Movimiento Campesino a Campesino, and has spread agroecology amongst farmers globally, were articulated in Nicaragua in the early 1980s. Agroecology found fertile ground in Nicaragua in that moment of the 1970s and 1980s because of its socio-political and economic situation and its role in the Cold War at that time. In 1979, after a decade of (armed) struggle, the Nicaraguan popular revolution overthrew the U.S.-supported puppet dictator, Anastasia Somoza, and Nicaragua became a beacon to anti-U.S. idealists around the world. Brigades of solidarity workers came to

Nicaragua to help with e.g. the coffee harvest or the national literacy campaign. During the 1980s, the low-intensity, U.S.-led 'Contra War' sapped much of Nicaragua's resources, and domestic policy encouraged looking inward, to national resources, for local solutions such as those offered by agroecological farming. Due to these juxtapositions of global and national events, and their impacts on the development of agroecology in the country, understanding Nicaragua's political history is important to fully understanding its key role in the global development of agroecology and its own national agroecological transition.

Chapter 3, the first empirical chapter, is based at the scale of the key individual actors – the farmers choosing to use agroecological practices on their farm. Farmers are the on-the-ground decision-makers: entrepreneurs experimenting with pro-environmental innovations like the use of agroecological practices. Authors have shown that individuals' personal norms - one's internalized social norms, that give one a sense of moral obligation to act in certain ways (see e.g. Jansson and Dorrepaal 2015) - are one of the strongest predictors of farmers' implementation of pro-environmental practices (Lokhorst et al. 2011; 2014; Lynne et al. 1995; Martínez-García, Dorward, and Rehman 2013; Price and Leviston 2014). Hence, I turn to social psychology, which provides insights into factors such as personal norms that inform users' (here, farmers') agency in enacting transition processes (here, adopting agroecological practices) (Greiner, Patterson, and Miller 2009; Noppers et al. 2014). Since farmers' enactment of farming practices may be gendered - i.e. differentiated according to male and female farmers - I explore if the adoption of agroecological practices and the strength of their personal norms differs between male and female farmers, and if so, what this means. The results and conclusions provide insight into men and women farmers' pro-environmental personal norms and their use of agroecological practices, with results pointing to recommendations for policy.

Chapter 4 explores the technological innovation system located inside the agroecological niche in Figure 5. To answer RQ2, I mapped the structures – the organizations, networks, and knowledge and market infrastructures – and how they enact the seven TIS functions over time, creating and growing Nicaragua's agroecological niche. At a national scale, the agroecological TIS consists of structures actively involved in creating framework conditions to support the scaling of agroecology – e.g. within financial resources, research and education, or input/output infrastructures. In this formative phase, which may involve cumulative small changes over decades, interested actors and organizations interact, form networks, align institutions, and accumulate knowledge, physical artefacts, and financial resources (Bergek, Jacobsson, and Sandén 2008). A process tracing of key events that analyzes changes in these functions shows the TIS' development over time (Kilelu, Klerkx, and Leeuwis 2013a; Weber and Rohracher 2012; Hekkert et al. 2007).

In Chapter 5, the niche perspective is turned outwards, exploring if and how, over time, the niche has linked to – 'anchored into' – the regime's structures, and to what extent the regime has changed to accommodate the niche. Conceptually set on the border between niche and regime, this chapter explores

the impacts the agroecological niche has had on the regime and the processes through which the niche has 'anchored' into the regime (Berkhout et al. 2010; Elzen, Van Mierlo, and Leeuwis 2012). It further asks to what extent the regime is changing to accommodate niche pressure: if it is reproducing itself without change, or re-aligning, transforming, substituting, or reconfiguring due to niche pressures (Grin, Rotmans, and Schot 2011; Geels and Schot 2007).

Chapter 6 picks up and synthesize the individual chapters' threads to give a rich, multi-level picture of the agroecological transition in Nicaragua. The thesis concludes with reflections on the findings' implications for agroecological and socio-technical sustainability transitions research, policy, and practice.

Chapter 2: Agroecology in Nicaragua: Context and background

2.1 Introduction

To aid in a better understanding of the empirical chapters that follow, this chapter provides an in-depth look at the socio-political context of agroecology's emergence in Nicaragua. As agroecology is inherently based in local contexts and experiences, this chapter discusses the structural and historical dynamics that shaped the emergence of agroecology. Understanding this history is important because structural and historical patterns shape the context and opportunities for change (Van Hecken et al. 2021), such as the move from conventional, fossil-fuel dependent agriculture to agroecology. Beginning with its roots in the environmental and social problems left by the Somoza regime, the chapter gives background information on its rise in the revolutionary Nicaragua of the 1980s, over the neoliberal period of the 1990s to the current government, in power since 2007.

2.2 Why history is important to understand Nicaraguan agroecology

This section provides background on the emergence of agroecology in Nicaragua, which can be linked to the political context following the 1979 Revolution and the resulting developmental vision and new agricultural policy. In 1979, after a decade of popular armed struggle, the Nicaraguan Revolution ousted the four-decade-long dictatorship of the U.S.-supported Somoza family. In this context of hope for new possibilities and opportunities, agroecology emerged in the early 1980s, partly as a response to problems inherited from the Somoza era and partly as a response to current issues of the time. To the present day, the Nicaraguan Revolution, which itself attempted to address the extreme inequalities of the Somoza era, and its legacy continue to strongly inform Nicaraguan politics. Several key elements that have shaped the development of agroecology in Nicaragua, such as the presence and power of farming cooperatives, are historically linked to the Revolution. Further, since the 1980s, national agricultural policy has changed significantly based on the political leanings of the party in power - and has impacted agroecology's growth in different manners. Therefore, an overview of Nicaragua's political economy and its agricultural context are important to fully understand its ongoing agroecological transition (Fréguin-Gresh 2017a). Figure 8 synthesizes each period's political frame conditions and key features of its agricultural policy, as discussed in this chapter.

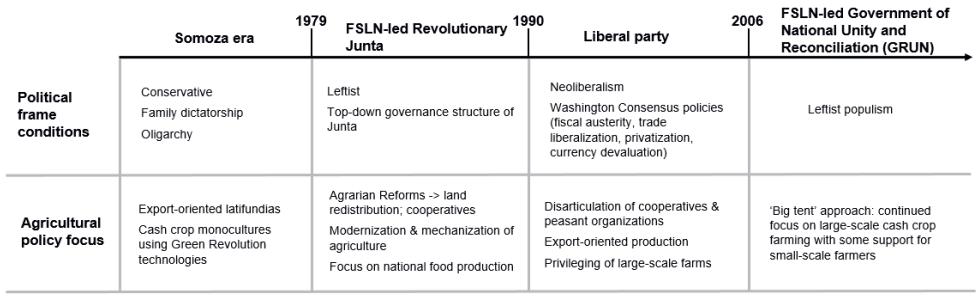


Figure 8: Timeline of the periods discussed in this chapter

2.3 The background to agroecology in Nicaragua

As mentioned in Chapter 1, agroecological practices have been used by smallholder farmers since agriculture began. The *milpa* system of Central America, briefly described in Chapter 1, is one such example. Many farmers in Nicaragua used the *milpa* system and other agroecological practices long before the emergence of agroecology described in this and the following sections occurred.

When agroecology emerged in an organized manner in Nicaragua in the 1980s, it was to address the pressing questions of deteriorating soil quality and environmental pollution (MAONIC 2011). Decades of agrochemical-input-intensive monocultures of export crops had leached the soil of its fertility, and in 1986 a soil and water conservation program supported by the Unión Nacional de Agricultores y Ganaderos (UNAG, the National Union of Farmers and Ranchers), the relatively new mass organization created to represent medium- and large-scale farmers' interests in the Revolution, invited a group of agroecological '*promoteres*' (farmer-extensionists) from Mexico to share their knowledge with Nicaraguan farmers (Holt-Giménez 2006). Zooming out to take a larger perspective, the Revolution sought to address the extreme socio-political and socio-economic inequalities exacerbated by the Somoza-era's export-oriented Green Revolution approach to agriculture. This resulted in a window of opportunity for the emergence of agroecology.

2.3.1 The legacy of the Somoza era

From 1934-1979, Nicaragua was ruled by the dictatorship of the Somoza family, who by the late 1970s managed 40% of the country's Gross Domestic Product (GDP) (Austin, Fox, and Kruger 1985), with a U.S. government report estimating the family's wealth at US$800 million in 1979 (King 1979). Government policy supported an export-oriented agri-industrialized model that displaced traditional basic grain cultivation, led to environmental destruction, and concentrated land ownership within the ruling oligarchy. By 1978, 37% of the economically active agricultural population was landless (Austin,

Fox, and Kruger 1985; Saravia-Matus and Saravia-Matus 2009), yet the Somoza family owned up to 80% of cultivated land in some areas (Rabella 2013). A 1981 environmental survey on water quality discovered that 75% of the country's water sources were contaminated by agricultural residues, 50% by sewage and 25% by highly toxic industrial waste (Larson 1989). Although Nicaragua's agro-export focus predates the Somoza era,[8] the continued expansion of the agricultural frontier, displacement of the rural population, intensive large-scale use of the agrochemicals necessary for cotton and banana production, and the consolidation of hacienda-style agriculture during the Somoza era exacerbated land degradation and pre-existing social inequalities.

When the first Somoza took power in 1937,[9] Nicaragua was lightly linked to the world market through its exports of coffee, bananas, lumber, and mining products (Biderman 1983).[10] Unlike neighboring countries, where large banana and coffee plantations dominated, several types of agrarian structures coexisted in Nicaragua (Martí í Puig and Baumeister 2017). Bananas, lumber, and mining were the main activities in the remote eastern region (although banana production waned rapidly in the 1930s), while coffee was produced mainly along the Pacific highlands. Coffee was produced on large-scale haciendas in a system akin to debt peonage, with the hegemony of the traditional landed oligarchy and workers given land to grow subsistence crops in return for their labor when required for coffee cultivation (Wheelock 1980; Biderman 1983). Alongside the haciendas existed peasant[11] subsistence agriculture (Martí í Puig and Baumeister 2017). The rapid expansion of cotton production in the 1950s consolidated the agro-export basis of Nicaragua's economy. The area of land under cotton quintupled between 1951 and 1955; production expanded at 33% a year in the early 1960s (Deere and Marchetti 1981; Biderman 1983). The economic benefits of this rapid expansion were not spread evenly, but rather accumulated almost exclusively to a small elite of large producers, who benefitted disproportionally from the Somoza government's support (Biderman 1983). Beyond cotton production, this support included preferential access to land facilitated through extensive road construction; favorable exchange rates and tariff and pricing policies, which stimulated investment in machinery and yield-increasing inputs; expanded credit; and the publicly subsidized provision of processing, storage, and market facilities as well as of research and irrigation (Biderman 1983). As the modern cotton production infrastructure supplanted

[8] Over the years. the agro-export focus crop moved from coffee (ca. 1880s to 1950s) over cotton (ca. 1950 to late 1960s) to beef (late 1960s to 1970s) (Deere and Marchetti 1981).

[9] Anastasio Somoza García helped to oust President Adolfo Díaz in 1928, and with the help of the U.S. Marine Corps became head of the National Guard in 1933. He then removed President Juan Bautista Sacasa and made himself President on January 1, 1937.

[10] Historically, Nicaraguan elites' focus rested on the construction of an interoceanic canal linking the Atlantic and Pacific coasts, rivaling the Panama Canal, to make them rich, not on plantation-style, export-focused agricultural development (Ortega Hegg 2013).

[11] Akin to the term *campesino*, this term is used in the traditional Nicaraguan vernacular to describe small, poor farmers and landless agrarian workers and their families that reside in rural areas and are juxtaposed against larger land-owning *finqueros* and *terratenientes*. In this thesis, the definition of *campesino* also includes indigenous groups and individuals who either self-identify as *campesinos* or fall under the above definition.

coffee haciendas and extended the agricultural frontier into national lands, the rural population of particularly Nicaragua's Pacific region was massively displaced (Deere and Marchetti 1981).

The expansion of cotton and, later, extensive cattle ranching meant smallholders were displaced from the most fertile lands, and food production pushed onto less fertile soils (Berth 2014). By the mid-1960s, basic grain production by smallholder farmers had fallen by 50% (Larson 1989). The cotton boom dispossessed the smallholder farmers who had produced food crops; the majority of the newly landless found employment only during the labor-intensive cotton harvest period (Deere and Marchetti 1981; Biderman 1983). Many farmers migrated to smaller plots or lower quality or less accessible land, often aided by the government's Instituto Agraria de Nicaragua (Nicaraguan Agricultural Institute, IAN), which since 1963 organized the opening of the agricultural frontier through infrastructural projects (and thus ensured a steady supply of labor for the burgeoning agroindustry) (Sabourin et al. 2017). Although agrochemicals were intensively used on land under cotton production, with the ensuing deterioration of soil quality, the opposite happened with food crops (Biderman 1983). Since smallholder food producers generally lacked access to agrochemical inputs and credit, the average yields for many food crops fell during the 1950s, with per capita food production declining in the 1950s, and per capita production of corn and beans continuing to stagnate into the 1960s (IFAD 1980). As the global cotton boom waned in the late 1960s, modern cattle ranches developed to take advantage of rising beef prices due to a developing market for processed meats and fast foods in the USA (Frenkel 1991). The amount of land dedicated to pasture doubled between 1960 and 1975, with beef exports increasing by 25% annually between 1965 and 1970 (Deere and Marchetti 1981).

By the late 1970s, 5 million acres of mostly recently deforested land was devoted to grain production and cattle production; food crops were produced on just 700,000 acres and of this, half was taken up by export crops (Barraclough and Utting 1987). Sugar, tobacco, and banana production for export increased (Biderman 1983), with exports of the five major agricultural products representing 66% of commodity exports between 1975 and 1979 (Weeks 1985). By the late 1970s, many rural workers lacked access to land as well as to secure employment sources. In 1978, the majority of agricultural laborers were either landless workers without access to permanent employment opportunities (40% of the agriculturally active population) or smallholder farmers generally unable to meet their subsistence requirements and hence compelled to supplement their income as wage laborers (38% of the agriculturally active population) (Deere and Marchetti 1981). Only 7.5% of the agriculturally active population was employed as full-time wage laborers (Deere and Marchetti 1981), and approximately 20% were landless wage workers who found employment only during four months every year, for the coffee, sugarcane, and cotton harvests (Ruchwarger 1987). The displacement of smallholder farmers lead to land concentration among a small elite of large land-owners, and land fragmentation, greater tenure insecurity, and landlessness amongst the majority of the rural population (Biderman 1983). Although 50.5% of Nicaragua's economically active population was employed in the agricultural sector in 1978 (around 430,000 individuals), ownership of the large farms (those larger than 353 hectares) was

concentrated among only around 1,600 persons (Deere and Marchetti 1981). These largest farms represented less than 2% of the total number of farms in the country, but controlled nearly half of the area under agricultural production (Biderman 1983). Extreme inequalities in land distribution were linked to extreme inequalities in credit access (Rocha 2020); in 1976, 90% of the state's agricultural credit supported cotton, coffee, and sugar production, all controlled by a small elite of large producers (Deere and Marchetti 1981; Saravia-Matus and Saravia-Matus 2009). Almost all of the elite were related to, or linked to, the Somoza family (Biderman 1983). The Somoza family itself was not just the country's largest landowner but indirectly or directly were involved with or controlled many related processing, marketing, financing, and infrastructural elements of agri-business. By the late 1970s, the Somoza family directly or indirectly controlled most of the seven export slaughterhouses for cattle in Nicaragua; was instrumental in developing the dairy processing industry; controlled five of the six large, vertically integrated firms that dominated the sugar industry; and were heavily involved in the tobacco industry (Biderman 1983).

An important consequence of the Somoza dynasty's export-centered agricultural production system and the oligarchic concentration of land and resources was the stagnation of the primary production of basic foodstuffs (Deere and Marchetti 1981). During the 1970s, the Somoza government "distinguished itself for its practically zero interest in food policy" (Berth 2014, 83, own translation). The expansion of areas under first cotton and then beef production meant the dispossession of many smallholder farmers, with the production of basic foodstuffs moving to areas with lower-quality soils (Berth 2014). Together, such land conversion, the dispossession of peasants, and the lack of state attention to the staple crops sector resulted in basic grain production failing to keep up with population growth (Deere and Marchetti 1981). The focus on agro-export production came at the expense of basic food production; since the 1950s, Nicaragua imported grain (Gilbert 1988). Although the land under production for food crops increased in the 1960s, and the Somoza government initiated several reformist activities and a national program to increase rice production through irrigation and mechanization, access to other food staples was patchy and expensive (Biderman 1983). These and other programs had a limited impact, and usually benefitted just a small elite (Biderman 1983). Illustrative of this is a 1981 survey of cotton and sugarcane plantation workers: 40% were illiterate and only 35% had access to land (Martí í Puig and Baumeister 2017). Fully half of the general population over ten years old was illiterate according to a 1980 census (Ministerio de Educación and Instituto Nacional de Estadisticas y Censos 1980). Food security and consumption patterns showed strong inequalities as well, with the rural population highly food insecure and facing much malnutrition while imported foods were consumed by the urban middle class and elites (Berth 2014).

2.3.2 The Nicaraguan Revolution inadvertently creates space for the early and rapid spread of agroecology

Four decades of the Somoza dynasty created many issues that drove divisive social tensions, including socio-economic inequalities; environmental pollution and destruction; the displacement of the rural population, who then moved to urban areas or the agricultural frontier; the concentration of resources; and the lack of an adequate and affordable food supply for the general population. With the aim of removing the Somoza dynasty from power and addressing the aforementioned and other socio-economic and socio-political inequalities, the Frente Sandinista de Liberación Nacional (National Sandinista Liberation Front, FSLN) led a popular uprising against the Somoza government throughout the 1970s, culminating in 1979 with the ousting of the last Somoza dictator. Post-victory, the Revolution was confronted with the legacy of the Somoza era: highly concentrated land ownership, low levels of production with sectoral and regional unevenness, high food insecurity of the population, and economic dependence on particularly U.S. trade, capital, and technology (Deere and Marchetti 1985). From 1979 until 1990, a Revolutionary Junta composed of FSLN leaders governed Nicaragua and attempted to address these issues through a framework based on Revolutionary ideals.

In 1981, ex-guardsmen of the Nicaraguan National Guard and other Somoza supporters, anti-Somocistas who felt betrayed by the Revolution, and others who opposed the Sandinistas began to wage a low-intensity war in opposition to the Revolutionary government. The U.S.-sponsored 'Contra War' (ca. 1981-1990), the civil war between those who opposed the Sandinistas and the Revolution (financed by the U.S.) and those who supported them, transformed Nicaragua into a central showplace of the Cold War in the 1980s.[12] Fueled clandestinely by the Central Intelligence Agency (CIA) through illegal arms

[12] Throughout the late 1970s, the Carter administration in the USA had followed a conciliatory approach towards Nicaragua, even when it became clear in late 1980 that the FSLN was supporting revolutionaries in neighboring El Salvador. To the Reagan administration that took office in January 1981, Nicaragua was a communist bastion in Central America. Fighting back against this perceived spread of communism in its sphere of influence was of such importance to the Reagan administration that, as of the early 1980s, it began covertly funding guerilla activities, through the CIA and to groups of anti-FSLN or pro-Somoza Nicaraguans (the 'Contras'), based on the Honduran border with northern Nicaragua. These activities were funded by the illegal sale of arms to Iran, then under an international arms embargo; over US$150 million were channeled through the CIA to Contra groups during the 1980s. Hence, the Contra War was the reason for what is known in U.S. politics as the Iran Contra Affair. As the Contra War began heating up in the 1980s, both Honduras and the USA denied the existence of CIA-funded Contra training camps on Honduran territory although their existence was documented in 1983 (Kinzer 1983). The USA categorically denied any involvement in such activities until 1986, when a CIA place carrying supplies for the Contras was shot down over Nicaragua, the pilot survived, and it became impossible to maintain the facade. The Iran-Contra Affair rocked the U.S. - between November 1986 and March 1987, President Reagan made three televised 'Addresses to the Nation' concerning Iran-Contra - and continuing support of the Contras proved untenable politically. With military aid from the U.S. cut off, a war-weary Nicaraguan population on both sides, and increasing international pressure, the Contras agreed to negotiations with the FSLN, with a voluntary demobilization of the Contras starting in December 1989.
In 1984, Nicaragua brought a case against the USA to the International Court of Justice (ICJ). In 1986, the ICJ ruled that the USA had violated international law by supporting the Contras in their rebellion against the Nicaraguan government, by mining Nicaragua's harbors, and by encouraging acts contrary to the general principles of humanitarian law, i.e. producing and distributing to the Contras the manual "Operaciones Psicológicas en Guerra de Guerrillas" ("Psychological Operations in Guerilla Warfare"). See also Brown University's excellent website for a timeline giving an overview of, and original documents pertaining to, the Iran Contra Affair (https://www.brown.edu/Research/Understanding_the_Iran_Contra_Affair/about.php) and

sales to Iran, the Contra War lasted until 1990, killing an estimated 20,000-30,000 Nicaraguan combatants and around 4,000 Nicaraguan civilians (Seligson and McElhinny 1996). Myriad nonlethal impacts of the Contra War perturbed Nicaraguan society for a decade and touched the life of nearly every Nicaraguan (Stanstifer 1981); for example, in just two years, between 1983 and 1985, 4,900 Nicaraguans were injured and 3,800 were kidnapped due to the war (Garfield, Frieden, and Vermund 1987). The Contra War formed the backdrop to the entire decade of the Revolutionary Junta.

The Revolutionary Junta that governed the country in the 1980s was formed by the FSLN and ultimately headed by Daniel Ortega after massive internal power struggles (Fernández Hellmund 2013). During this time, policies, rhetoric, and ideologies emphasized sovereignty, autonomy, and food self-sufficiency through domestic production (Godek 2015). The Revolutionary government was determined to promote food security, nutrition, and a more equitable distribution of land and income; these issues were directly linked to its fundamental goals of strengthening national sovereignty and creating a more egalitarian society through a "New Economy" (Biondi-Morra 1993). Sweeping land reforms (eventually impacting three million of the country's five million hectares of farmland) and a rural literacy-building campaign were cornerstones of the Revolutionary government's plans to transform the countryside (Martí í Puig and Baumeister 2017). The literacy campaign, based on the humanist pedagogy developed by Brazilian educator Paolo Freire (Baracco 2004), who came to Nicaragua to advise on the campaign in late 1979 (Hanemann 2006), was purported to have lowered Nicaragua's illiteracy rate from 50% to 13% in the five months of its implementation in 1980 (Stanstifer 1981).

As part of the effort to address the immense environmental destruction left by the Somoza regime, and based on an impulse from civil society (as explained in section 2.3.3 below), the Revolutionary government created the first environmental agency, the Instituto Nicaragüense de Recursos Naturales (Nicaraguan Institute for Natural Resources, IRENA, which later became the Ministry of the Environment and Natural Resources, MARENA), which received international funds to operate (Junta de Gobierno de Reconstrucción Nacional 1979). A law was passed decreeing Nicaraguan national territory as the property of the people and government of Nicaragua, prohibiting extraction by foreign corporations and the export of endangered species[13] (Envio 1989). The creation of IRENA allowed the Revolutionary government to introduce an environmental agenda to its policies aimed at the agricultural sector, and to initiate a series of environmental protection programs, such as the targeting of 18% of national territory as new national parks (Envio 1989; Fréguin-Gresh 2017a).

Yet, when it came to agriculture, the Revolutionary government focused on modernizing agricultural food production using the most advanced technologies at hand at the time, prioritizing the mechanization of production, ensuring the financing of irrigation projects, and supporting the use of agro-chemicals

Stephen Kinzer's excellent book, based on his many years as a journalist based in Managua and covering Nicaragua in the 1980s, 'Blood of Brothers' (Kinzer 1991).

[13] During the last Somoza president, Nicaragua exported more rare and endangered species than any other Central American country (Envio 1989).

(Martí í Puig and Baumeister 2017). To ensure that economic growth would benefit all, state enterprises were developed as cornerstones to grow the domestic food system and ensure national food security (Biondi-Morra 1993). The Revolutionary government's Agrarian Reform was the backdrop to agroecology's emergence in the early 1980s, and also encouraged several issues that were to be instrumental to agroecology's emergence and continuous spread in Nicaragua: environmental issues caused by agro-chemical intensive forms of agricultural production, the organization of rural workers and farmers into cooperatives, and land redistribution. Although discontent with the first Agrarian Reform, particularly concerning individual land ownership (land was distributed through cooperatives, as explained below), spurred the second Agrarian Reform of 1986, the productivist focus of the Revolutionary Junta's agrarian policy did not change.

The Agrarian Reform of 1981 provided the backdrop of agroecology's development later that decade. The Revolutionary government's Agrarian Reform aimed to transform Nicaragua's agricultural production based on five pillars: land re-distribution; the conversion of private land into state-owned and collective lands; increased access to credit; the centralization of imports, exports, and food distribution mechanisms under the state; and the organization of workers into cooperatives and unions (Castro et al. 2016; Martí í Puig and Baumeister 2017). First were land reforms that expropriated lands owned by the Somoza family and their allies (including soldiers and officials of the defeated regime), and the conversion of these areas into state-owned farms and collective cooperatives (Martí í Puig and Baumeister 2017); the confiscated farms totaled 21% of the total area under cultivation nationwide (Zalkin 1987). Land distribution and the property structure fundamentally changed between 1978 and 1984, with the amount of farms larger than 140 hectares decreasing by half (Martí í Puig and Baumeister 2017). At first, this land was converted into state properties or given to new, state-affiliated credit, services, and land cooperatives, who together administered almost 40% of the total national farming area by 1984 (Martí í Puig and Baumeister 2017), but individual farmers did not benefit as private land ownership was forbidden (Dore and Weeks 1992; Rocha 2020). The question of private land ownership lead to widespread disillusionment and discontent with the FSLN in the rural population (Fréguin-Gresh 2017a), and by 1984 it became clear that many peasants in the war zones were supporting the Contras (Dore and Weeks 1992). Seeking to gain the rural population's approval, 1985's Second Agrarian Reform re-distributed land from cooperatives to individual farmers, among other issues (Dore and Weeks 1992; Martí í Puig and Baumeister 2017).

Table 3 illustrates these changes in land ownership.

Table 3: Changing land ownership in Nicaragua (numbers given in thousands of hectares) (Everingham 2008, 70; based on INRA 1997)

Farm size	1978		1988		1996	
	No.	% of total	No.	% of total	No.	% of total
Private sector						
>350 ha	2,044.0	36.2	423.4	7.5	447.7	7.7
140-350 ha	917.7	16.2	733.7	13.1	851.0	14.9
35-140 ha	1,701.7	30.1	1,606.9	28.4	1,611.0	29.2
7-35	868.7	15.4	808.6	14.3	899.5	15.6
<7	119.0	2.1	132.0	2.3	137.6	2.3
Reformed sectors						
Individual			501.7	8.9	1,106.6	19.2
Cooperative			781.0	13.8	519.8	9.3
State farm			663.7	11.7	0.0	0.0
Worker enterprise					104.2	1.8

Note: Total arable land (100%) was 5.651 million hectares

The second pillar was to increase agricultural production through the modernization of state-owned farms and cooperatives and the intensified use of agro-chemicals, machinery, and irrigation (Martí í Puig and Baumeister 2017). This lead to unprecedented levels of government investment in the agricultural sector, but because the modernization of food production, based heavily on the imports of goods and supplies, was prioritized and organized through government entities, the public sector absorbed around 70% of the resources (compared to the 25% and 5% that the cooperative sector and the private sector received, respectively) (Utting 1988; Martí í Puig and Baumeister 2017).

The third pillar consisted of increasing producers' access to credit and funding through state development banks (Martí í Puig and Baumeister 2017). Through nationalization of the banking system, the credit system was expanded, and by 1988 had doubled public financing to two-thirds of the agricultural sector (Martí i Puig and Baumeister 2017). The largest benefits accrued to the public sector and medium-sized and large farmers, although smaller farmers and cooperatives also profited from increased productivity (Martí í Puig and Baumeister 2017); by 1985, peasants received up to 31% of total agricultural credit (Wiggins 2006). This expansionary credit policy proved unsustainable for the government and did not provide the expected returns on increasing agricultural productivity, as much of the credit was used to purchase consumption goods rather than invested into production improvements (Barraclough and Utting 1987; Enríquez 1991; Biondi-Morra 1993). In 1988, public support for

cooperatives and smallholder agriculture was eliminated for a complete focus on large-scale, mechanized food production (Cussianovich and Altamirano 2005).

The fourth pillar sought to bring exports and imports under direct state control while controlling domestic trade by instituting public mechanisms to collect, acquisition, and distribute food (Martí í Puig and Baumeister 2017). To control domestic trade, authorities set price controls for essential food products, with set selling prices for producers and set purchasing prices for consumers, and with state-owned companies carrying out the collection and distribution of basic consumption goods (Montano 2009). Forcing producers to sell to the state damaged the existing traditional private market structures and triggered both a rapid fall in production as well as the rapid growth of a black market with prices much higher than the official ones (Dore 1990, 109).

The fifth pillar consisted of organizing workers and farmers into cooperatives and trade unions linked to the Revolutionary government (Martí í Puig and Baumeister 2017). The Revolutionary government's strong commitment to cooperatives as a mode of rural development was based in socialist ideology, but also on the practices of national hero Augusto Sandino (Núñez Soto 2015), who from 1927-1933 led an insurrection against the U.S. occupation of Nicaragua and in the 1930s organized around 3,000 producers into cooperatives in the liberated northern part of Nicaragua (Utting, Chamorro, and Bacon 2014). The two main types of cooperatives in the agricultural sector were Cooperativas Agrícolas Sandinistas (Sandinista Agrarian Cooperatives, CAS), where land was farmed collectively; and Cooperativas de Crédito y Servicios (Credit and Service Cooperatives, CCS), in which each farmer tended his/her land individually but associated to access credit and other support services, and to market produce (Utting, Chamorro, and Bacon 2014). By 1984, CAS had been given a total of 2.4 million acres of land, or 24% of the productive land in Nicaragua (Holt-Giménez 2006).

Agricultural production was stifled in the 1980s due to both internal causes - the negative side-effects of the Agrarian Reforms, as outlined above - and external causes. The on-going low-intensity Contra War and, as of 1985, the U.S.'s economic embargo, caused widespread insecurity in the countryside and severely negatively impacted agricultural productivity (Saravia-Matus and Saravia-Matus 2009). The Contra War impacted agricultural production in several direct and indirect manners. As the main fighting activities took place in rural areas, farming itself became dangerous (Larson 1989). Many people decided to join or were conscripted into one side or the other's forces, leading to a depletion of the rural work force (Soto 2020). Many rural inhabitants were displaced by the fighting (Larson 1989). With roads and areas controlled by one side or the other, input and marketing supply chains were disrupted (Larson 1989). The nascent Revolutionary government was forced to divert large amounts human and economic resources from development projects and ecological programs to defense projects and the later effects of the U.S. trade embargo (Larson 1989), reducing the amounts available for supporting peasant agriculture and food production. Responding to the continuing agression of the Contra War, in September 1983 the Revolutionary Junta passed a law that made military service compulsory for all

Nicaraguan males over the age of 18 (Soto 2020). Aiming to bolster the fatigued and depleted Sandinista army, this policy caused further depletion of the rural work force (and backfired) as young men either fled the country to avoid serving or joined the Contras before being forced to join the Sandinista army (Soto 2020). It strongly increased popular negative sentiment toward the FSLN (Soto 2020) and was a major factor in the FSLN's fall from power in the 1990 elections.

Nicaragua's economic situation deteriorated rapidly as of 1985. Since 1981, the Reagan administration had gradually been imposing restrictions on U.S. trade with Nicaragua. Credit was denied through the U.S. Import-Export Bank, meaning Nicaragua had to pay cash for all imports from the U.S., and the administration cancelled Overseas Private Investment Corporation (OPIC) insurance for Nicaraga, thereby substantially increasing risk to investors (Leogrande 1996). In 1983, Nicaragua's share of the U.S. sugar quota was reduced by 90% (Leogrande 1996). As of 1985, a full trade embargo by the U.S. cost Nicaragua an estimated US$50 million per year for the five years of its duration (Leogrande 1996). Anticipating the deterioration of its relationship with the U.S., the Nicaraguan government had reduced bilateral trade with it from 30.4% in 1980 to 14.9% in 1984 and strengthened its trading with Western Europe and Japan (from 20.6% to 35.1%) and the Soviet bloc (from 1% in 1980 to 15.4% in 1984) (Leogrande 1996). In the late 1980s, Nicaragua experienced severe recessions successively, culminating with the economy contracting by 15% and inflation reaching 33,600% in 1989 following the government's 1988's austerity measures (Leogrande 1996) - another reason for the FSLN's loss in the 1990 elections. As the economic and political pressure increased, so did the intensity of the Contra War (Martí í Puig and Baumeister 2017). Unfavorable prices on a wide range of agricultural commodities as well as the sudden removal of government subsidies for agricultural credit in inputs in 1988 meant that many small-scale farmers ended up heavily in debt (Ravnborg 2008). Agricultural productivity fell in all sectors, except for the production of basic grains (Martí í Puig and Baumeister 2017).

The negative economic situation greatly reduced the possibilities of importing key agricultural inputs, including agro-chemicals and machinery, for conventional agriculture, so a search for alternative, local, no-input forms of agricultural production began (Cussianovich and Altamirano 2005; Gonzálvez, Salmerón, and Zamora 2015; Fréguin-Gresh 2017a). Government institutions such as the Ministerio de Desarrollo Agropecuario y Reforma Agraria (Ministry of Agricultural and Livestock Development and Agrarian Reform, MIDINRA) began developing projects supporting alternative forms of agriculture and experimenting with organic agri-inputs. IRENA began to promote reforestation programs, experimented in agro-forestry projects with cultivating basic grains alongside trees, and organized the local production of organic agri-inputs (Larson 1989; Cussianovich and Altamirano 2005; Gonzálvez, Salmerón, and Zamora 2015). The Universidad Nacional Autónoma de Nicaragua (National Autonomous University, UNAN) in León developed and disseminated an integrated pest management program (Cussianovich and Altamirano 2005; Gonzálvez, Salmerón, and Zamora 2015). A biogas production project was begun by the UNI (Universidad de Ingeneria) and the National Agricultural School in Rivas (Cussianovich and Altamirano 2005; Gonzálvez, Salmerón, and Zamora 2015).

During the 1980s, framed by the Cold War, the Nicaraguan Revolution was an international symbol of hope for leftists (Carroll 2008). To the international Left, the Nicaraguan people had themselves shaken off the chains of oppressions and were attempting to build a more egalitarian society. As news of the Contra War began leaking into the international press in the early 1980s, international solidarity with Nicaragua burgeoned, and idealistic youth came from overseas to support the Revolution as international brigades of e.g. coffee harvest workers or literacy teachers. The idealism of the Revolution was high, and many Nicaraguans and internationals were excited by new ideas and opportunities. During meetings, working alongside, and exchanges between Nicaraguans and internationals, many of whom were in the country to experience the new era and learn from the Revolution, co-learning occurred and new ideas were fomented (Godek 2014). Inspired by learnings from these exchanges between Nicaraguan farmers and international volunteers, many Nicaraguan CSOs[14] became interested in and began focussing on (agro)ecological agriculture. The horizontal learning pedagogy of the Campesino a Campesino (CAC) movement further continued the spread of local and newly-gained knowledge on agroecological practices among farmers and CSOs. Solidarity groups from Western Europe began importing organically produced coffee from Nicaragua, spurring international exchanges and the development of organic and fair-trade value chains and structures (Garibay and Zamora 2003).

2.3.3 Agroecology emerges in Nicaragua

With the Revolution and its massive social and agrarian changes as the backdrop, agroecology emerged in the early 1980s as a response to several issues: the government's industrial approach to agriculture and the ensuing environmental problems, but also ongoing economic problems and instability from the fomenting Contra War. Its emergence was also linked to the international spread of the environmental movement, which led to fertile exchanges between Nicaraguans and foreigners who visited or worked in Nicaragua and brought new ideas on how to address local problems. Individuals interested in biodiversity conservation and environmental protection began coming together in Managua in a series of meetings out of which would arise the Nicaraguan Environmental Movement, MAN (further detailed below). Farmers and organizations began looking for locally-based solutions to address environmental degradation and low agricultural productivity stemming from decades of agri-industrial farming, particularly cotton production (Fréguin-Gresh 2017b), and spreading knowledge through new farmer-to-farmer networks. Discussing the development of the related idea of food sovereignty (in which agroecology forms the basis for political action for food system change) in the 1980s, Godek (2014) points out that "this period was described more as one during which the formative ideas around the

14 Following usage in Nicaragua and Obuch (2014), I differentiate between international non-governmental organizations (NGOs) and national civil society organizations (CSOs). Further distinct are social movements, e.g. PCAC-UNAG, ATC, La Via Campesina and others, which tend to be more ideological, with national social movements more or less closely linked to the Revolution and Sandinista ideology.

concept were emerging and nurtured with the ideas and values of the Revolution, the exchanges between Nicaraguan peasant organizations and those based internationally as well as international NGOs and cooperation agencies, and the emergence of movements like CAC and MAN with their focus on ecological agriculture" (Godek 2014, 129).

Between 1982 and 1984, small producer cooperatives and groups, international NGOs, national CSOs, and commercialization and certification organizations began to promote agroecological and organic agriculture as methods of agricultural production (MAONIC 2011), usually as part of projects focused on environmental protection (Cussianovich and Altamirano 2005). In 1986, agroecology began to be promoted by the Unión Nacional de Agricultores y Ganaderos (National Union of Farmers and Ranchers, UNAG),[15] who since then has played a central role in fomenting agroecology in Nicaragua. UNAG had partnered with the Mexican NGO SEDEPAC to establish a farmer-run soil and water conservation program based on horizontal knowledge sharing with several cooperatives in Nicaragua (Holt-Giménez 2006). Initial attempts were not too promising and adoption was low due to several reasons. First, the cooperatives worked on a schedule of yearly plot rotations to give every farmer access to the best areas, so the farmers were wary of investing labor in plots they only farmed for a year; second, cooperative members had good access to cheap credit and external inputs; third, cooperatives usually had plentiful access to land, so when a plot was exhausted, they moved on; and finally, cooperatives focused on extensive beef production were simply not interested (Holt-Giménez 2006). Further, the ongoing war increased the instability of cooperatives' membership, with farmers joining the cooperatives for a few seasons before heading on a tour of duty. This instability increased the difficulties of instituting the experiential knowledge base necessary for the farmer-led approach (Holt-Giménez 2006). Finally, the pilot efforts were successful in several small, pro-Sandinista credit and service cooperatives, particularly around Santa Lucía in Boaca, who pressured UNAG to expand the program (Cussianovich

[15] During the Revolutionary government's early years, (late 1970s and early 1980s), two Sandinista mass organizations were formed that later became instrumental in agroecology's emergence and spread in the country and internationally. The organizations were meant to represent the voices of the small- and medium-sized farmers and the landless rural workers in the Revolution: respectively, UNAG, formed in 1981, and the Asociación de Trabajadores del Campo (Rural Workers' Association, ATC), formed in March 1978 (Ruchwarger 1985; Luciak 1995; L. MacDonald 1997). Although UNAG and ATC both pushed for agrarian reform, their foci differed as per the different groups of farmers they served (Deere and Marchetti 1985; Ruchwarger 1987; LaRamée and Polakoff 1999). The ATC focused much of its attention on securing minimum wages for workers in both state-owned enterprises and the largest private companies, as well as enabling access to land for its members and unionizing landless agricultural workers; UNAG emphasized expanding access to productive resources for its members and growing cooperatives (Ruchwarger 1987; Luciak 1995; Martí í Puig and Baumeister 2017). In the early 1980s, with UNAG members representing 66% of the rural economically active population and 28% of the general economically active population, it significantly influenced the government's agricultural policies (Ruchwarger 1985). As the small- and medium-sized farmers produced nearly all of Nicaragua's foodstuffs at the time - 80% of beans and corn, and 97% of the vegetables consumed in the country - one of UNAG's main goals was to increase this production to overcome the basic grain shortage and increase food security (Ruchwarger 1985). Hence, in line with the Revolutionary government's agrarian reform, UNAG's first tasks focused on helping peasants gain access to land, the allocation of credits to its members, and aiding farmers in organizing agricultural inputs (machinery, seeds, fertilizer, irrigation equipment) in order to increase production of basic foodstuffs (Ruchwarger 1985).

and Altamirano 2005; Holt-Giménez 2006; Gonzálvez, Salmerón, and Zamora 2015). As the Mexican and Nicaraguan farmers exchanged visits and experiences, trust between them grew and a politically grounded, horizontal co-learning to find real solutions developed. Beyond transferring agricultural technologies, farmers were "making culture" and creating a knowledge base of shared information and wisdom (Holt-Giménez 2006). The farmer-to-farmer methodology (CAC for its name in Spanish, Campesino a Campesino) developed out of these and other experiences, and has since been implemented by hundreds of thousands farmers across Central America and around the globe (Gonzálvez, Salmerón, and Zamora 2015). As it became more strongly institutionalized, the Nicaraguan Programa Campesino a Campesino (PCAC) was eventually housed under UNAG (and referred to as PCAC-UNAG), where it has been since 1986.

Concurrently, Nicaragua's environmental movement coalesced during the late 1970s and 1980s as a response to the legacy of agro-export development, in particular the environmental destruction due to cotton production, and to the introduction and promotion of Green Revolution technologies to increase production before and during the Revolution (Godek 2014). The Movimiento Nicaragüense Ambiental (Nicaraguan Environmental Movement, or MAN), was formed by the Association of Biologists and Ecologists of Nicaragua with the aim of creating an ecological movement with a broad popular base (Larson 1989). MAN emerged as concerned individuals began coming together in Managua in the late 1970s (but formally existed as an organization only between 1988-2009), specifically aiming to address the environmental problems caused by land use change to monoculture production, associated contamination of water sources, and the use of improved seeds requiring larger quantities of agrochemicals (Godek 2014; Sabourin et al. 2018). MAN aimed to create widespread public awareness of these issues and catalyzed the creation of Nicaragua's first ministry of the environment, IRENA, in 1979. In its first project, showcasing organic coffee production, which piqued interest in farmers throughout the region, MAN used not just pro-environmental arguments, but the high cost of pesticides as an argument to convince small producers to go organic (Envio 1989; Larson 1989). MAN also functioned as an early certification agency for international coffee export, mainly to solidarity groups in Western Europe (Garibay and Zamora 2003). MAN was crucial to the early development and spread of agroecological thought in the 1980s and 1990s, and its members have since gone on to spread agroecology through formal roles in a myriad of organizations at national level.

In conclusion, the emergence of agroecology in Nicaragua in the 1980s can be seen as a response to several issues: to the industrial agricultural approach continued by the Revolution and the associated issue of environmental degradation, and also to the economic and political difficulties faced by Nicaraguan society. The early (in international comparison) and strong emergence of agroecology in Nicaragua in the 1980s was driven by several groups of actors, including farmers and farmer cooperatives (in the PCAC movement) and civil society actors (in the formation of MAN). It happened in the context of the Revolution, was influenced by exchanges between Nicaraguans and internationals, and partly in response to the Revolutionary government's industrial approach to agriculture and

associated environmental destruction. Figure 9 gives an overview of the main organizations and networks involved in strengthening agroecology in Nicaragua, to be discussed in greater detail in the following sections and in the next chapters.

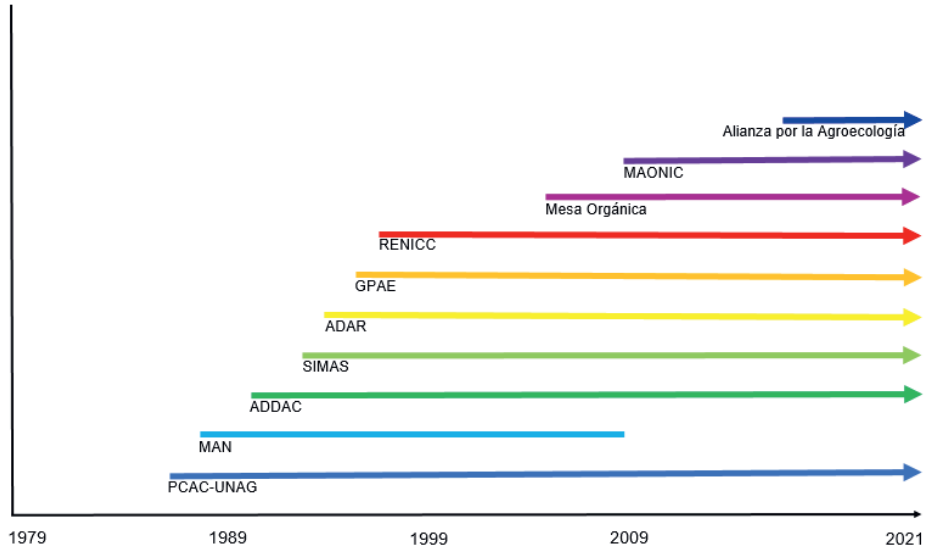


Figure 9: Timeline of central organizations involved in agroecology in Nicaragua

2.3.4 Agroecology flourishes in the neoliberal era between 1990 and 2006

In the 1990 general election, the FSLN lost to an alliance of Liberal parties, which until 2006 pursued a neoliberal agenda, with three consecutive governments embracing Washington Consensus policies (fiscal austerity, trade liberalization, and privatization, coupled with currency devaluation) (Jonakin 1996; McCune et al. 2016; Godek 2015). With the switch to three successive neoliberal governments, state interest in agriculture turned to the privatization of the agri-food production system and a re-orientation to production for export. Significant reforms made during the Revolution were rolled back as the government's economic development model took a renewed focus on liberalization and market-based economic growth (Godek 2014; Martí í Puig and Baumeister 2017). Together with the slashing of state support for agriculture, a process of disarticulation of the peasants' and rural workers' organizations and the cooperative structure began (Martí í Puig and Baumeister 2017). Nicaragua began free market reforms and International Monetary Fund (IMF) structural adjustment programs in 1991 (Pisani 2003; HabibMintz 2004). State credit and public technical assistance diminished radically (Martí i Puig and Baumeister 2017) which impeded (small) farmers' possibilities of increasing productivity and competing in global markets (Ripoll 2018). With fiscal austerity, support for social programs introduced during the Revolution disappeared (Prevost 1996). Access to productive resources

diminished with the disappearance of the Revolution's agrarian reform programs, resulting in the weakening and disappearing of cooperatives, reductions in the amount and availability of credit, and land concentration (Godek 2014). Market liberalization favoring international exchange, coupled with currency devaluation, greatly increased prices of agri-inputs (Godek 2014). Further land reforms, seeking to amend parts of the Sandinista land reform and privatize cooperative and State areas, exacerbated land ownership issues (Broegaard 2005; Saravia-Matus and Saravia-Matus 2009) and increased particularly small farmers' land tenure insecurity and food insecurity (Cussianovich and Altamirano 2005).

A triggering factor for and germ of the future development of agroecology was the rapid increase of national CSOs, many financed by international NGOs and formed by now-unemployed political cadres of the Revolution, who promoted many types of sustainable agriculture projects (Gonzálvez, Salmerón, and Zamora 2015). The drawback of the state from social and development programs in 1990s Nicaragua led to what has been referred to as a "CSO explosion": while the number of CSOs granted legal status in Nicaragua totaled 114 during the 1980s, 1,615 new CSOs were registered between 1990 and 1997 (Borchgrevink 2006, 22). As peasants and small producers continued to organize, albeit at local and departmental levels, CSOs and NGOs stepped into the breach and began supporting more farmer groups and cooperatives (Martí í Puig and Baumeister 2017). Since the neoliberal governments did not involve themselves with agroecological projects, most were conceived and implemented by CSOs and NGOs (MAONIC 2011). Many people associated with MAN and now unemployed carried agroecological ideas into many of these projects, or founded their own CSOs to address environmental protection from various angles, many of which involved agroecological elements.[16]

Many CSOs and NGOs began working with small farmers on sustainable agriculture projects, focusing on transforming agricultural production through soil conservation, agricultural diversification, integrated pest management, support in organizing producers, research and training, and the promotion of commercialization (Gonzálvez, Salmerón, and Zamora 2015). A cooperation between international groups (mainly German organizations emerging from the international solidarity movement with the Sandinista Revolution) and Nicaraguan technicians led to the formation of the CSO Asociación para el Fomento de la Agricultura y el Medio Ambiente (Association for the Promotion of Agriculture and the Environment, SOFAMA). One of SOFAMA's projects, run with the support of MAN and concerning the production and marketing of organically produced coffee, was important to two aspects of agroecology's development in Nicaragua: the rescue and application of local farming knowledge and techniques, and the laying of the seeds for the formation of the Grupo de Promoción de Agricultura Ecológica (Group for the Promotion of Ecological Agriculture, GPAE). The 1994 formation of GPAE, originally constituting some 70 CSOs and independent agroecological professionals, was catalyzed by

[16] Although MAN officially dissolved in 2008, its members spread into Nicaraguan universities, government entities, NGOs, research institutes and other organizations. They were, and continue to be, influential in fomenting agroecological thought into different sectors.

MAN. GPAE was conceived as an intermediary and coordinator between the different organizations and actors working to support agroecology (Cussianovich and Altamirano 2005). It is a network of organizations committed to ecological agriculture and agroecology. Since its inception, GPAE has aimed to promote agroecological concepts and practices; coordinate local, national, and international exchanges of experiences in agroecology;[17] stimulate the valorization of farmers' knowledge of traditional and agroecological practices and support the collection and dissemination of traditional knowledge of agroecological practices; contribute to development of agroecology at the national level; and promote gender equality (Cussianovich and Altamirano 2005). In the late 1990s and early 2000s, GPAE emerged as a key actor. In partnership with local organizations, it developed agroecological projects all around the country and organized a diagnostic study on organic production in Nicaragua (Garibay and Zamora 2003; Gonzálvez, Salmerón, and Zamora 2015). GPAE was instrumental in increasing pressure on the government to propose an agroecology law, and decisively contributed to formulating proposals for the law.

Other CSOs emerged that focused on the sharing of agroecological knowledge, both within Nicaragua and internationally (SIMAS), agroecology as an essential aspect of rural development (ADAR), and developing value chains for agroecological products (RENICC). The Servicio de Información Mesoamericano sobre Agricultura Sostenible (Mesoamerican Information Service on Sustainable Agriculture, SIMAS) was created in 1992. With the backing of international development agencies, SIMAS organized the formation of working groups, composed of diverse institutions interested in ecological agriculture, on the topics of pest management, alternative forms of credit, agroindustry, commercialization, and cover crops (Cussianovich and Altamirano 2005). SIMAS continues to be a beacon of information on agroecology, publishing manuals on these and related subjects, supporting other agroecological organizations, and working directly with farmers on their agroecological transitions. The Asociación para el Desarrollo Agroecológico Regional (Association for Regional Agroecological Development, ADAR) emerged in the early 1990s as the first organization to systematically use the term 'agroecology'; GPAE for example uses 'ecological agriculture' and 'agroecology' synonymously (Gonzálvez, Salmerón, and Zamora 2015). ADAR has since focused on promoting permaculture and bio-intensive agriculture using a territorial development approach, often in conjunction with SIMAS, the Universidad Nacional Agraria (National Agricultural University, UNA) and other organizations. Not many organizations focused explicitly on creating value chains for agroecological products. An exception is the Red Nicaragüense de Comercio Comunitario (Nicaraguan Network for Community Commerce, RENICC).[18] Learning from experiences with exporting organic coffee with the international fair trade and solidarity movements, RENICC was founded in 1996. RENICC focuses on building networks of community commerce, based on fair trade and agroecological principles, across the Nicaraguan regions. It does so through supporting local farmers' markets, creating

[17] For example, GPAE is part of MAELA.
[18] http://www.renicc.org.ni/

community stores where farmers can both sell their products and purchase agri-inputs, participating at local and regional fairs, and facilitating farmers' centers for information and agri-inputs such as seeds.

In the countryside, the spread of agroecological methods continued to grow during the 1990s; by the early 2000s, more than 14,000 producers used ecological methods (MAONIC 2011). UNAG continued the CAC program (referred to as PCAC-UNAG) although the program weakened in the 1990s especially with the effects of market liberalization (Godek 2014). Agroecological methods were spread in projects and programs targeted at integrated rural development with an ecological focus, but the projects remained isolated, without a vision for broader territorial development (MAONIC 2011). Rather, these projects focused on improving production and raising yields of farms, organizing farmers into groups, and improving farmers' living conditions (MAONIC 2011). An example is the CSO Asociación para la Diversificación y el Desarrollo Agricola Comunal (Association for the Diversification and Development of Communal Agriculture, ADDAC)[19], in the northern Nicaraguan municipality of Matagalpa, who formed in 1990 to promote sustainable agricultural, productive, commercial and associative development. ADDAC supports farmers in organizing cooperatives, creating added value by further processing steps, and marketing their products, and have played an instrumental role in creating a deep base of agroecological knowledge and farmer cooperatives. CSOs emerged that link agroecology to related issues, like social justice and women's empowerment, such as OCTUPAN[20] and the Fundación Entre Mujeres (FEM)[21] in Estelí, in northern Nicaragua. NGOs like the Community Agroecology Network (CAN) worked in partnership with farmer cooperatives to foster agroecology. Some groups focused on agroecology as a tool for environmental protection and landscape conservation, like the farmer organization Foro Miraflor[22] outside of Estelí, while others promoted organic agriculture as a solution to small farmers' problems of an insecure food supply and the lack of inputs for agricultural production (Cussianovich and Altamirano 2005).

A series of hurricanes during the 1990s, most notably 1998's Hurricane Mitch, were instrumental in increasing interest in agroecology among farmers (Fréguin-Gresh 2017b; Conz 2018). Hurricane Mitch left almost 900,000 Nicaraguans homeless due to mudslides and floods (UN-ECLAC 1999), with extreme destruction of the agricultural landscape in some areas. Participatory research done in paired parcels of destroyed cropland (agroecological/conventional under the same topographical conditions) in the central hills demonstrated the outstanding effects that agroecological farm management had on both the productivity and the resilience of crop production on the plots. Agroecologically farmed plots were less devastated than those farmed using conventional methods and recovered high levels of crop

[19] https://cluster-nicaragua.net/organizaciones/asociacion-para-la-diversificacion-y-el-desarrollo-agricola-comunal-matagalpa
[20] "Octupan" means "place of great roads" in the indigenous Chorotega language. For more information on Octupan , please see https://ocsi.org.es/2017/08/24/asociacion-octupan-lugar-de-grandes-caminos-condega-nicaragua/
[21] https://www.femnicaragua.org/quienes-somos
[22] https://ucamiraflor.org/quienes-somos/

productivity faster (Holt-Giménez 2002). These results encouraged many farmers and organizations to adopt agroecological practices and the farmer-to-farmer method (Gonzálvez, Salmerón, and Zamora 2015). International scientists such as Eric Holt-Giménez, Peter Rosset, and Miguel Altieri were instrumental in divulging these results showcasing the resilience and productivity of these agro-ecosystems due to the use of agroecological methods (e.g. Holt-Giménez 2002; 2006). Nicaragua gained international attention in agroecology circles, and international agroecology networks like the Sociedad Científica Latinoamericana de Agroecología (Latinamerican Scientific Society for Agroecology, SOCLA) began to get involved in Nicaragua (Gonzálvez, Salmerón, and Zamora 2015), including on issues such as the use of transgenic crop varietals (Altieri and Nicholls 2003) and in education events and courses (Gliessman 2002).

Nicaraguan organizations strengthened their ties to international agroecological movements and organizations. In 1991, UNAG participated in the founding of one of the first transnational peasant organizations, the Asociación de Organizaciones Campesinas de Centroamérica para la Cooperación y el Desarrollo (Central American Association of Rural Organizations for Cooperation and Development, or ASOCODE) (Godek 2014). UNAG was the most consolidated peasant organization of Central America at the time, and played a central role in ASOCODE[23], including housing its first regional headquarters (Edelman 1998). PCAC-UNAG and other experiences of cross-border organizing in Central America formed the roots for what would become La Via Campesina (Godek 2014). La Via Campesina (LVC) emerged from the space created by transnational peasant organizing in Latin America, including the experiences of PCAC-UNAG, ASOCODE and others, during the early 1990s (Edelman 2008; Godek 2014). Nicaraguan peasant and farmer organizations, particularly PCAC-UNAG and the Asociación de Trabajadores del Campo (Rural Workers' Association, ATC), played fundamental roles in this process[24] (Godek 2014). Two further factors spurred the mobilization of peasants and farmers in Nicaragua and around the globe in 1992: the commemoration of 500 years since Columbus' arrival in the Americas and the Rio Earth Summit in Rio de Janeiro (Godek 2014). Considering the former, rural movements, and indigenous and afro-descendent communities united to commemorate 500 years of resistance in parallel to the official acts of remembrance (Godek 2014). Parallel to the Rio Earth Summit, rural and indigenous organizations congregated to Vitoria in the state of Espiritu Santo in Brazil, where they held an official meeting and other parallel meetings (Godek 2014). Exchanges between peasant organizations, with the strong participation of Nicaraguan peasant organizations, lead to the formation of the regional peasant network Coordinadora Latinoamericana de Organizaciones del

[23] "The basis for the founding of ASOCODE was the common acknowledgement that peasant organizations in the Central American region faced similar challenges, including, but not limited to, the effects of violence and conflict that characterized the region in the 1980s; the implications of market-led reforms on rural communities, peasants, and production; the effects of agricultural modernization and Green Revolution technologies on both production and environmental quality; and the marginalization of grassroots groups from policymaking (Edelman 1998)" (Godek 2014, 134) ASOCODE was a high-profile player in Central American politics between 1991 and 1998 (Edelman 2008).

[24] UNAG left LVC in 1986 or shortly thereafter (Godek 2014, 145).

Campo (Regional Coordination of Latin American Rural Organizations, or CLOC) in August of 1992[25] (Godek 2014). In this context of early 1992, prior to the Rio Earth Summit, an important event took place that led to the creation of LVC: UNAG convened an international meeting of peasant and farmer organizations to commemorate its 10 year anniversary (Godek 2014). Although LVC was officially created in Belgium in 1993, in 1992 this congress of farmers from Nicaragua, Latin America, and Europe first identified similarities between their struggles, brought their agendas closer together and identified ways to take action together (Godek 2014). The Managua Declaration, one of LVC's founding documents, was born from this process, as was LVC itself (La Via Campesina 1992; Edelman 2008). It was in this context, while farmers from all parts of the world searched for alternatives and solutions to problems they had in common, that the concept of food sovereignty emerged (Godek 2014).

Besides the international social movement networks, international scientific and funding relationships influenced the development of agroecology in Nicaragua. Local and cross-border knowledge-building and sharing on agroecology was promoted through projects supported by international research institutes, such as the Centro Agronómico Tropical de Investigación y Enseñanza (Tropical Agricultural Research and Higher Education Center, CATIE), and CSOs like SIMAS. The rise of fair trade promoted by international cooperative movements in the 1990s further promoted projects on agroecology (Gonzálvez, Salmerón, and Zamora 2015) (although fair trade's impacts on the food security and livelihoods of farmers in Nicaragua were later shown to be patchy; see (Bacon et al. 2014; Bacon 2015). Regional agencies, such as the Instituto Interamericano de Cooperación para la Agricultura (Inter-American Institute for Cooperation on Agriculture, IICA) began funding more agroecologically-focused projects. Together with other large-scale funders of agroecology projects, such as SwissAid and CAN, a plethora of international groups fund smaller projects across the country.

In the early 2000s, the environmental movements (e.g. for the protection of water sources, for biodiversity preservation, or against the introduction of genetically modified organisms (GMOs) in Nicaraguan agriculture) and social movements (e.g. for food sovereignty), began to organize themselves and gained a stronger political voice. Each of these movements expressed their opposition to the government's neoliberal policies and free trade agreements that sought to privatize natural and productive resources, e.g. water; liberalize agricultural and food trade; and divest control over genetic resources to transnational institutions and companies (Godek 2014). CSOs emerged to tackle these issues, with much organizational overlap in terms of membership in the movements and the networks that represented them (Godek 2014). Many individuals active here were already active in one of the social movements or CSOs discussed above, such as SIMAS, LVC, ADAR, GPAE, or MAN, and/or affiliated with national research institutes such as UNA. The Alianza por un Nicaragua Libre de

[25] CLOC later became a member of LVC, representing peasant organizations at the regional level, and subsequently becoming a key player in knowledge production and exchange regarding Latin American agroecology, with CLOC universities located around South America teaching agroecological theory and practice (REFS). The ATC, UNAPA, and MAF all later became members of LVC as well as regional peasant networks like CLOC.

Transgénicos (Alliance for a Nicaragua Free of Transgenics) formed in 2002 over concerns that transgenic corn was being sent to Nicaragua as part of food aid from the World Food Program (Godek 2014). The Alliance later changed its name to the Alianza de Protección a la Biodiversidad (Alliance for the Protection of Biodiversity) and remains an important supporter of agroecology at the national and Central American levels (APB-N 2018).

2.3.5 2006 to the present: National institutionalization of agroecology

The FSLN and their candidate, Daniel Ortega, won 2006's general election with 38% of the vote. Since then, they have remained in power. While this has opened new spaces for engagement, enabling a successful push by producer organizations, CSOs, and social movements to codify a national legal framework supporting agroecology, the implementation of the latter has remained difficult.

When Daniel Ortega (re)assumed the presidency in 2007, his administration was believed by many to represent increased opportunity for the rural sector, and particularly peasants. Ortega's electoral campaign included a promise to adopt policies to provide "massive credits and subsidies to producers" (Martí í Puig 2008, 290), and the government inherited a complex social situation that was characterized by significant poverty, especially in rural areas. The expectation was that Daniel Ortega would live up to his professed commitment to social redistributive programs that would improve the conditions of the most vulnerable and least fortunate (Spalding 2009, 368). In practice, the economic approach adopted and implemented by the Ortega government has had mixed impacts on peasants and rural communities. This can be attributed to the two-pronged economic development strategy pursued by the Ortega government. On the one hand, the government continued the neoliberal macroeconomic development policies of the three preceding conservative governments that privilege large-scale agriculture. On the other hand the government has simultaneously introduced a broad network of socially-redistributive policies and programs funded mostly from Venezuelan oil, that, in the case of the rural sector, have sought to reactivate production by small and medium farmers and reduce poverty (Close 2016; Martí í Puig and Baumeister 2017). These policies have benefitted some peasants, while also disenfranchising others. For example, the selection of beneficiaries of social programs has been reportedly clientelistic in nature, with supporters of the FSLN being prioritized (Bay-Meyer 2013; Baumeister and Martí í Puig 2018; Cuadra Lira 2018). Moreover, the development model has explicitly prioritized extractive policies (Thomas 2017) and large-scale development projects as an engine for economic development. This had devastating impacts on rural communities, often leading to displacement and loss of economic opportunities to produce.

In 2008, UNA opened the first post-graduate degree program in agroecology, at Master's level, followed in 2015 by an agroecology PhD program. UNA has been a key player supporting agroecology in many aspects: through formal agroecological research and its two degree programs, but also by involving itself

in agroecology through various means, such as through government channels and through cooperations with NGOs and farmer organizations.

In 2011, the Law on Agroecology and Organic Production was passed. This law was the outcome of ten years of work by a broad coalition of social movements, activist unions, and academics (Le Coq et al. 2020), as discussed above. The law was discussed and formulated in a nationwide stakeholder consultation process, the largest political consultation ever organized in Nicaragua (Gonzálvez, Salmerón, and Zamora 2015). This process was led by a new CSO, the Mesa Orgánica (Organic Roundtable), formed in 2007 by several dozen CSOs, unions, government entities, and universities (MAONIC 2011). Many individuals involved with organizations that grew during the 1990s and early 2000s, such as GPAE, MAN, SIMAS, ADAR, and with government-affiliated institutions such as PCAC-UNAG and UNA, were involved in the Organic Roundtable. The Organic Roundtable was formed to bring together, for the first time at a national level, public and private actors and synergize their efforts, resources, and capacities (MAONIC 2011). Between February 2007 and December 2008, the Organic Roundtable worked on projects that laid the groundwork for the agroecology law. Three hundred and forty-eight leaders (33% of which were women) from 153 farmer organizations, collectives and other organizations involved in ecological agriculture participated in a total of 16 departmental fora, one in each of Nicaragua's administrative departments (MAONIC 2011). Participants came from farmer organizations, unions, cooperatives, and CSOs, together with the UNA, MAGFOR, and IICA) (MAONIC 2011). Besides debating the formulation of the two laws, participants discussed the principles of agroecology and organic production in the Nicaraguan context, and put together a document of the vision for and mission of agroecology and a systemic plan for implementation of an agroecological agricultural system nationwide (MAONIC 2011).

The national technical standards for agroecology, NTON 11-037, the appendage to Law 765 composed of norms and technical standards for agroecological production, emerged as the government's response to international market demands for certified products, and in support of the cooperative agro-export sector (Gonzálvez, Salmerón, and Zamora 2015). With the NTON, the government aimed to promote organic agriculture with agroecological features and create a public certification for agroecological production, for registration with international certification bodies (Gonzálvez, Salmerón, and Zamora 2015). The Organic Roundtable organized the contested processes of agreement on the NTON standards (Gonzálvez, Salmerón, and Zamora 2015). Many Nicaraguan agroecologists have criticized the NTON for representing solely the technical implementation of agroecological practices, and for not considering other dimensions of agroecology (Fréguin-Gresh 2017a).

The Movimiento de Productoras y Productores Agroecológicos y Orgánicos de Nicaragua (Movement of Agroecological and Organic Producers of Nicaragua, MAONIC) was born out of this nationwide stakeholder consultation processes (MAONIC 2011). Since then, MAONIC has coordinated with the Ministerio Agropecuario y Forestal (Ministry of Agriculture and Forestry, MAGFOR, now known as

MAG) to support the scaling of agroecology at farm, national, and regional levels. MAONIC defines agroecology as a return to peasant practices (MAONIC 2011). Since its inception, it has contributed to scaling agroecology nationally and within Central America. At farm level, through its extension activities, MAONIC has reached 20,650 producers and trained 2,150 promoters/technicians in good agroecological practices (personal communication). It has systematized farmers' agroecological experiences (contributing to the transformation of tacit knowledge into scientific knowledge) and, based on these, published good agroecological practices in technical manuals (personal communication). At the national level, MAONIC was heavily involved in the process and formulation of the Agroecology Law and accompanying technical standards (NTON 11-037) (personal communication). Regionally, MAONIC participated in the process of elaboration and agreement on the Central American technical regulations for organic products (personal communication).

International and Nicaraguan groups joined in several networks in the 2000s. In 2007, groups working on agroecology and the related subject of food sovereignty joined in the Alianza Semillas de Identidad (National Alliance "Seeds of Identity", ASI) (Trucchi 2007). The ASI was implemented simultaneously in Nicaragua, Ecuador, and Colombia, with the goals of visualizing and highlighting the importance of native seeds, as well as rescuing and giving value to the countries' large biodiversity (Trucchi 2007). In Nicaragua, the ASI was financed by SwissAid and implemented by GPAE, PCAC-UNAG, the Nicaraguan chapter of the Alliance for the Protection of Biodiversity, and the Grupo de Interés sobre Soberanía y Seguridad Alimentaria y Nutricional (Interest Group on Food and Nutritional Sovereignty and Security, GISSAN) (Trucchi 2007). In 2014, the Alianza por la Agroecología (Alliance for Agroecology) was formed to bring together social organizations promoting agroecology in 7 Latin American countries (besides Nicaragua, Bolivia, Guatemala, Paraguay, Ecuador, Colombia, and Brazil). Linked to the debate on the use of native vs. transgenic seeds in Nicaraguan agriculture, the Alliance for Agroecology is explicitly in favor of native seeds and a ban on transgenics in Nicaragua (Alianza por la Agroecología 2014a). At the international level, PCAC-UNAG and SIMAS participate for Nicaragua. At national level, the Alliance for Agroecology works closely with organizations like GPAE, MAONIC, ASI, and research institutes like UNA (SIMAS 2014). Figure 10 illustrates relationships between the most active organizations working in agroecology in Nicaragua.

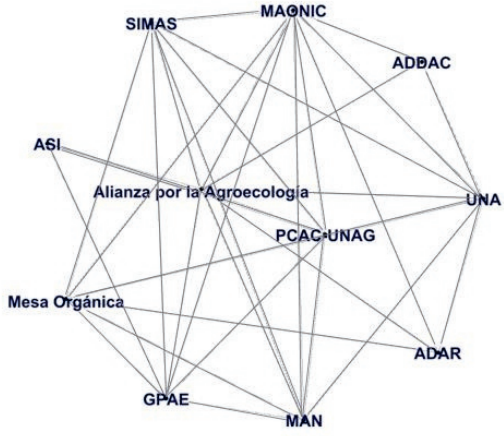


Figure 10: Network map of organizations playing key roles in Nicaraguan agroecology

The national government has adopted a systemic view of agroecology. Figure 11 shows the government's conceptualization of a national agroecological system, centered on the family farm as a hearth hold ('mi casa'). The hearth hold includes the house as such, with food preparation and sanitary facilities, potable water, and pets. The second tier indicates the farm ('mi patio'), and includes livestock, trees (fruit and timber), bees as pollination services, and plants (edible and medicinal). The third tier ('mi comunidad') widens to cover secondary forests and larger agroforestry and sustainable livestock production systems. Regional issues such as water sources and market connections inform the tiers.

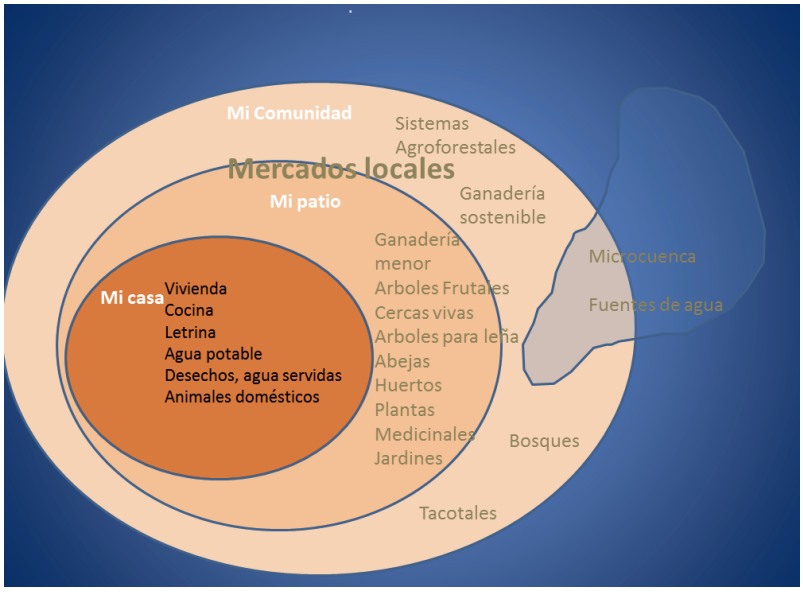


Figure 11: Schematic representation of Nicaragua's agroecological system, based in the household (MAGFOR 2013, 18)

In 2019, the GRUN re-affirmed its commitment to agroecology and formalized a plan, with the support of the Food and Agriculture Organization of the United Nations (FAO), to develop specific policy instruments in support of an agroecological transition (FAO 2019). Government institutions such as the Ministerio Agropecuario (Ministry of Agriculture, MAG), the Ministerio de Economía Familiar, Comunitaria, Cooperativa y Asociativa (Ministry of Family, Community, Cooperative and Associative Economy, MEFFCA), the Instituto Nicaragüense de Tecnología Agropecuaria (Nicaraguan Institute of Agricultural Technology, INTA), the Instituto de Protección y Sanidad Agropecuaria (Institute of Agricultural Protection and Health, IPSA), and MARENA, universities and research groups (UNAN-León, UNA), CSOs and social movements (particularly MAONIC), and firms that have been marketing organic products from Nicaragua (coffee, cocoa, fruit) in national and international markets will participate in the process of elaborating these new policy instruments.

2.4 Current data on agroecology in Nicaragua

Like most countries, Nicaragua does not collect national-level data on agroecological production or producers (although it does do so for organic production). However, based on the last national agricultural census (from 2011), which asked about the agricultural practices used on farms, Fréguin-Gresh (2017a) extrapolated an estimation of the number of farms that use at least one agroecological

practice.[26] As illustrated in Table 4, only 34% of farms do not use any type of agroecological practice. However, this does not mean that the other 66% (a total of 173,280 farms) are fully agroecological, but rather that one or more agroecological practices are used on the farm. During the same census, respondents estimated the number of agroecological producers to be between 20,000 and 30,000 (of the total 262,546 farms counted during the census) (Fréguin-Gresh 2017a). MAONIC and PCAC-UNAG specify that 20,650 farms that are registered as agroecological, or 7.9% of all farm holdings in Nicaragua from the 2011 census (personal communication). Most of these farms are small (less than 5 hectares) or medium-sized (less than 50 hectares) (personal communication). The difference between these numbers - 173,280 farms using at least one agroecological method vs. 20,650 known agroecological farms - illustrates two key challenges of agroecology. First, defining what exactly constitutes an agroecological farming system is difficult. Second, agroecological production is often not a black-or-white issue, but instead takes place along a gradient, with farmers using more or less agroecological practices next to conventional ones, depending on their needs.

Table 4: Number of farms in Nicaragua that use agroecological practices (Fréguin-Gresh 2017a based on the IV National Agricultural Census of 2011)

Number of agroecological practices used on farm	Number of farms	% of all farms surveyed for census
None	89,400	34%
1	65,426	25%
2	54,233	21%
3	29,591	11%
4	13,111	5%
5	6,025	2%
6	2,581	1%
7	1,184	0.5%
8	560	0.2%
9 or more	435	>0.2%

Since national-level data do not exist, identifying the main crops that are grown agroecologically is challenging. However, a study from the National Agrarian University based on conventional and

[26]Agricultural practices covered by the census that were considered agroecological include contour lines, retention barriers, cover crops, live fences, no-tillage practices, windbreaks, post-harvest practices, no-burn practices, organic fertilization, crop rotation, fire prevention rounds, and others.

agroecological farmers in seven municipalities of the department of Carazo, in southwestern Nicaragua, shows that only a minority of agroecological farmers grow the staple crops (maize, beans, rice, sorghum) and perennial crops (coffee, bananas, fruit trees); many have livestock (chickens, pigs, cattle, horses, sheep) (Matamoros Guerrero 2017). Many farmers that are certified organic for export crops such as cocoa and coffee use agroecological methods on the rest of their farm (personal communication). Crops that are grown for own consumption and local markets include vegetables such as yucca, peppers, gourds, cabbage, and black-eyed peas; fruit crops like bananas and plantains, chilies, papayas, mangoes, and lemons; herbs; and medicinal plants (Samper Kutschbach et al. 2020; Centro Humboldt 2022). Chapter 3 takes a deeper look at practices used and crops grown by agroecological farmers.

2.5 Looking forward from this contextual basis

This chapter has illustrated the context in which agroecology emerged in Nicaragua. Issues stemming from the Somoza era - environmental destruction, socio-economic inequities - framed the emergence of agroecology; international exchanges of knowledge fertilized it; and it was shaped by the explicit search for locally sourced solutions to the aforementioned issues. Interestingly, the same issues that created the space for agroecology's emergence during the Revolutionary Government in the 1980s did not differ much from those that led to the Revolution happening in the first place: divisive social tensions, including socio-economic inequalities; environmental pollution and destruction; the displacement of the rural population, who then moved to urban areas or the agricultural frontier; the concentration of resources; and the lack of an adequate and affordable food supply for the general population.

Beginning from the starting point provided by this chapter, the upcoming chapters (Chapters 3, 4, and 5) expound upon the development of agroecology in Nicaragua since then. Chapter 3 takes a farmer-focused perspective, Chapter 4 explores how organizations have worked together to support agroecology, and Chapter 5 investigates the processes through which these organizations have attempted to change the dominant agri-food regime. In Chapter 6, lessons from Chapters 3, 4, and 5 are synthesized.

Chapter 3: Exploring the relationship between gender and personal norms in the adoption of agroecological practices

Abstract

Individuals' pro-environmental personal norms are an important predictor of their enactment of pro-environmental practices. Although much recent research includes social psychological factors when analyzing farmers' decision-making, the question of differences between male and female farmers remains under-examined. Contributing to this discussion, this paper studies the adoption of agroecological practices by male and female farmers, and explores the relationship between male and female farmers' pro-environmental personal norms and their adoption of agroecological practices. The quantitative case study is based on a survey of 119 farmers in northern Nicaragua. We find that most farmers grow a diversity of crops using a diversity of agroecological practices. The stronger male farmers' pro-environmental personal norms are, the more agroecological practices they tend to adopt. Female farmers' adoption of agroecological practices is not found to be driven by the strength of their pro-environmental personal norms. The results point to the importance of integrating socio-psychological data and gender background into planning when considering policy and programs to support farmers in transitioning to more sustainable forms of agricultural production, for example by integrating socio-psychological questions into pre-programmatic research and including female stakeholders in planning, from the early problem definition phase on.

3.1 Introduction

Farmers are the central actors determining the use of pro-environmental methods, including agroecology, on their fields (Darnhofer, Gibbon, and Dedieu 2012). Male and female farmers' decision-making and enaction of farming practices are shaped by social and cultural values and beliefs, biophysical and institutional factors (e.g. access to land, inputs, labor, credit), and other forms of work enacted by each (e.g. paid labor, care work) (Greiner, Patterson, and Miller 2009; Mills et al. 2017; Engler, Poortvliet, and Klerkx 2019). Farmers' decision-making concerning which practices to use is hence influenced by a host of considerations, including biophysical, market-related, infrastructural, and socio-economic issues, as well as their individual psychological characteristics and social factors (Greiner, Patterson, and Miller 2009; Mills et al. 2017; Engler, Poortvliet, and Klerkx 2019). As the issue of gender shapes access to all components of food systems (Schipanski et al. 2016), it is a central, yet often overlooked, question in the literature on the adoption of pro-environmental farming methods, such as agroecological practices (Akram-Lodhi 2015; Sarrouy Kay, Lemke, and Pimbert 2016; Bezner Kerr et al. 2022). Gender differences in agricultural decision-making can adversely affect farming families' food security, as research from Malawi has shown (Nyantakyi-Frimpong et al. 2016). Hence, understanding differences in male and female farmers' decision-making to adopt new practices is important to better target policies, programs, and projects to farmers' individual needs.

Although much research concerning farmers' decision-making to adoption new technologies and practices has focused on explanatory characteristics that are extrinsic to farmers (e.g. structural variables), the importance of intrinsic factors (e.g. processes of learning and experience, farmers' perceptions and personal norms) has increasingly been recognized (Marra, Pannell, and Abadi Ghadim 2003; Pattanayak et al. 2003; Pannell et al. 2006; Rossi Borges et al. 2014; Senger, Borges, and Machado 2017; Bopp et al. 2019). Hence, some research has started incorporating social psychological approaches, which allow for more a comprehensive understanding of technology adoption (Bopp et al. 2019). A growing body of work demonstrates that farmers' implementation of new pro-environmental technologies and practices are influenced by their attitudes, norms, and propensity to change (Ahnström et al. 2009; J. Jansen et al. 2009; Niles, Lubell, and Haden 2013; Meijer et al. 2014; Fang, Ng, and Zhan 2018; Gholamrezai, Aliabadi, and Ataei 2021; Hallaj et al. 2021; Tang, Liu, and Long 2021; Ataei et al. 2022). Personal norms - one's internalized social norms, that give one a sense of moral obligation (see e.g. Jansson and Dorrepaal 2015) - have been shown to be one of the strongest predictors of farmers' implementation of pro-environmental practices (Lokhorst et al. 2011; Martínez-García, Dorward, and Rehman 2013; Price and Leviston 2014; Lokhorst et al. 2014; Hallaj et al. 2021; Tang, Liu, and Long 2021). While some studies on the impact of gender on environmental behavior suggest that female farmers are more pro-environmentally oriented than male farmers, other studies observed no significant relationship between farmers' gender and their environmental behavior (although no studies show men

as having stronger pro-environmental personal norms) (Zelezny, Chua, and Aldrich 2000; Burton 2014). Yet, although authors have shown differences between male and female farmers concerning their personal norms and their pro-environmental behaviors (e.g. Gholamrezai, Aliabadi, and Ataei 2021), the question of gender continues to be understudied in the socio-psychological adoption literature. This is unfortunate, because a comprehensive understanding of these processes could yield important insights to better target agricultural policies and programs (Greiner, Patterson, and Miller 2009; Bopp et al. 2019) and better engage farmers in environmental management through consideration of farmers' norms and motivations, as not all farmers respond equally to incentives (Mills et al. 2017; Mutyasira, Hoag, and Pendell 2018; Bopp et al. 2019).

Aiming to increase the resilience of farming systems to both gradual impacts of climate change and extreme climate events (Altieri et al. 2015), agroecological farming is based on ecological principles and practices for the design and management of sustainable agroecosystems (Altieri and Nicholls 2012). As outlined in Table 5, agroecological practices are based on the provision of ecosystem services and on spatial and temporal functional diversity. Both of these serve to increase the resilience of the farmed land towards climate events, such as drought, rainstorms, wind, etc. Further, they serve to make the farm less reliant on external agro-chemical inputs, which may not be available at the correct times or at an appropriate price to farmers in rural, logistically not well-connected areas. It is important to note that beyond this article's farm-centered focus, agroecology refers more broadly to the ecology of food systems (Francis et al. 2003) and is a key issue in global actions towards environmental and social justice and sustainable agri-food systems (IAASTD 2009; FAO 2018a; 2018c; HLPE 2019b). In the agroecological literature, gender is often not explicitly addressed, although implicitly included in agroecology's twin aims of ecological and social wellbeing (Zaremba et al. 2021; Bezner Kerr et al. 2022). Although often, female farmers are the visible or invisible actors involved in adopting agroecological practices (Rosset and Altieri 2017), gender has yet to be systematically integrated in agroecological analyses,[27] as is also the case for related fields such as food sovereignty (Park, White,

[27] Discussions around gender in agroecology are often from an ecofeminist perspective (see e.g. Rosset and Altieri (2017). Ecofeminism ties together feminist and ecological principles, linking the oppression of women to that of the natural environment (Howell 1997). Seeking to overcome oppression of all forms, ecofeminism is inclusive of the diverse experiences and opinions of men and women, and is particularly grounded in the 'local' (Rao 2012). While a large body of literature develops ecofeminist thought (see Allison (2010) for a review and Phillips and Rumens (2017) for a contemporary perspective addressing essentialist critiques, discussed below), essentialist ecofeminist work has been criticized for locating the dominion of women and nature in ideology (Banerjee and Bell 2007; Rao 2012). Women are often conceptualized as inherently closer to nature, which infers the homogenization of all women, regardless of geographic, cultural, economic, and historic differences, neglecting "interrelated material sources of dominance based on economic advantage and political power" (Agarwal 1992, 122), and thereby perpetuating the stereotype of women as caretakers and nurtures while simultaneously limiting women from expanding to their full range of potentialities and abilities (Momsen 2000; Emmons Allison 2010; Rao 2012).
Further, ecofeminism has been criticized for being based mainly on anecdotal evidence ideology (Banerjee and Bell 2007; Rao 2012), and for failing to link theory with action – i.e. for not providing empirical proofs of how ecofeminist theory can be translated and operationalized into practical actions (Jewitt 2000). Ecofeminism has been revisited in the past years in view of its contributions to intersectional frameworks seeking to represent and capture the specificity of discrimination faced by marginalized groups, e.g. Black women (Kings 2017). Not

and Julia 2015). Authors writing on gender differences in the adoption of agroecological practices such as agroforestry often focus on socio-economic or technological aspects of adoption (Kiptot, Franzel, and Degrande 2014), including personal determinants such as marital status and religion, and unequal access to resources, such as farm inputs, financing, extension, and information sources (Murage et al. 2015; Mutenje et al. 2016). Male and female farmers in eastern Africa experience and perceive the benefits of a specific adoption differently; these perceptions are important shapers of their decisions to adopt innovative pro-environmental practices (Murage et al. 2015). Concerning social psychological factors like personal norms and agroecology, research is even sparser. A study in Brazil, focused on agroecology academics, not farmers, found that men tended to have weaker beliefs concerning agroecology's socioeconomic and cultural dimensions, while women tended to have stronger beliefs concerning its sociopolitical and environmental dimensions (Fiamoncini and Pato 2020).

Table 5: Agroecological principles for the design of biodiverse, energy efficient, resource-conserving and resilient farming systems (Altieri and Nicholls 2012, 9)

Enhance the recycling of biomass, with a view to optimizing organic matter decomposition and nutrient cycling over time.
Strengthen the "immune system" of agricultural systems through enhancement of functional biodiversity - natural enemies, antagonists, etc.
Provide the most favorable soil conditions for plant growth, particularly by managing organic matter and enhancing soil biological activity.
Minimize losses of energy, water, nutrients and genetic resources by enhancing conservation and regeneration of soil and water resources and agrobiodiversity.
Diversify species and genetic resources in the agroecosystem over time and space at the field and landscape level.
Enhance beneficial biological interactions and synergies among the components of agrobiodiversity, thereby promoting key ecological processes and services.

Contributing to these discussions, this paper investigates the relationship between farmers' gender and pro-environmental personal norms concerning their adoption of agroecological practices, based on a quantitative survey of 119 male and female smallholder farmers held in northern Nicaragua in 2014. The paper focuses on two research questions:

wishing to contribute to the "myth [that] women are intrinsically better stewards of the environment" (Doss et al. 2018, 72), the research presented in this chapter nonetheless provides empirical evidence of the different effects male and female farmers' personal norms have on their adoption of agroecological practices.

1) What are similarities and differences in the adoption of agroecological practices by male and female farmers?

2) Is there a relationship between farmers' gender and their pro-environmental personal norms, and does this inform their adoption of agroecological practices?

In the next section, the conceptual underpinnings from social psychology are detailed, explaining how a focus on individual personal norms can aid in illuminating farmers' implementation of pro-environmental practices, and questioning how this relates to farmers' gender. Data-gathering and analysis methods are described in section 3.3. Results are presented and discussed in sections 3.4 and 3.5. Section 3.6 concludes the chapter with reflections on implications for supporting male and female farmers' transitions to agroecological farming.

3.2 Analytical framework: Measuring the relationship between pro-environmental personal norms and the adoption of pro-environmental practices

In the broadly used values, beliefs, and norms (VBN) tradition, which has been used successfully in agricultural contexts to measure farmers' pro-environmental attitudes (Martínez-García, Dorward, and Rehman 2013; Lokhorst et al. 2014), personal norms are some of the most important determinants of individuals' behavioral change toward acting in a more environmentally friendly manner (Price and Leviston 2014). Personal norms are self-expectations based on internalized values, and relate to individuals' sense of personal responsibility, their awareness of their needs, and their awareness of the consequences of their actions (or inaction) (Lokhorst et al. 2014; Mills et al. 2017). Because individuals wish to maintain a positive self-concept and to be morally responsible, their personal norms are posited to be a direct predictor of their behavior (Mills et al. 2017). Hence, farmers' pro-environmental personal norms can be linked to their motivations and intentions to adopt pro-environmental practices on their farms (Ataei et al. 2022). Borrowing from VBN, which has developed a well-validated set of measures to quantify individuals' pro-environmental personal norms (further detailed in section 3.3 below), a framework investigating possible link between farmers' gender, their pro-environmental personal norms, and their adoption of agroecological practices was developed (see Figure 12). Agroecological practices were grouped according to their contributions to basic agroecosystem processes (Altieri 2002) and are listed in Table 6.

As outlined in the previous section, research on gender differences concerning individuals' pro-environmental personal norms and farmers' adoption of pro-environmental practices, specifically agroecology, has been inconclusive and sparse. While much research has shown the different constraints female farmers face (see e.g. Doss et al. 2018), which influence their decision-making concerning the adoption of agroecological practices, little research has focused on possible differences between male and female farmers concerning their personal norms and enaction of agroecological practices. A study

from Iran showed that female farmers' personal norms tend to be more strongly influenced by social norms than are male farmers', suggesting that although personal norms reflect one's internal values, they are also influenced by other people's expectations (Gholamrezai, Aliabadi, and Ataei 2021). Contributing to this discussion, and as outlined in Figure 12, this study aims to take a closer look at the relationship between farmers' gender and their pro-environmental personal norms and how this influences their adoption of agroecological practices, grouped according to standard agroecological practice. To do so, concepts from VBN theory are operationalized to provide empirical evidence of the relationships questioned in the analytical framework, as detailed in the following section.

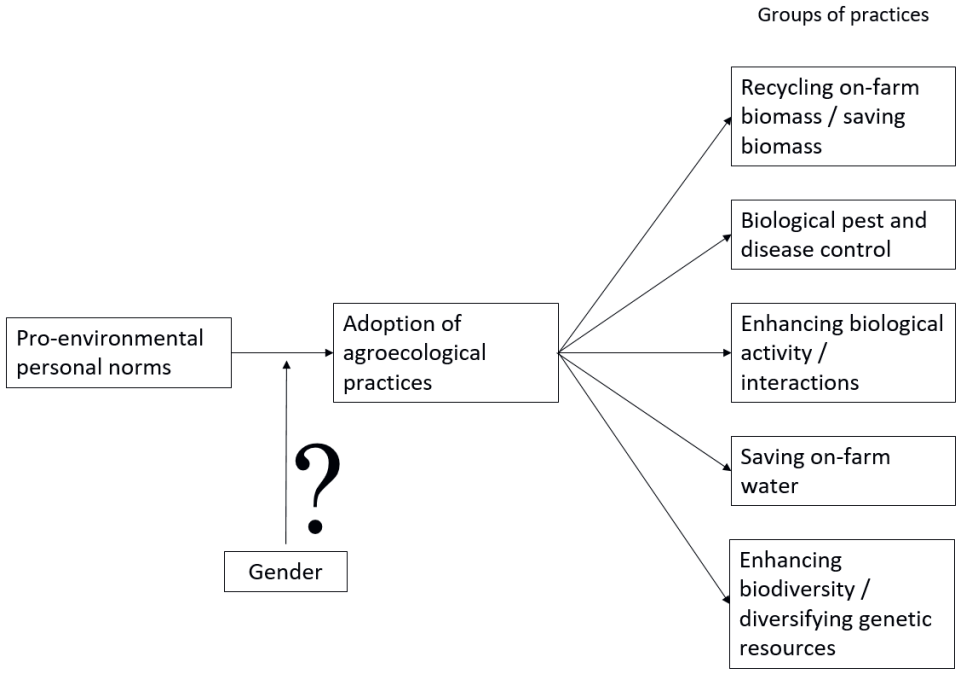


Figure 12: Placing the research question within the analytical framework: Is there a relationship between farmers' gender and their pro-environmental personal norms that influences their adoption of agroecological practices?

3.3 Materials and Methods

3.3.1 Participants and design

This research is a survey-based quantitative case study analysis of smallholder farmers' personal pro-environmental norms and their adoption of agroecological practices in northern Nicaragua. Using a closed-question survey, data was collected from 119 participants around the municipalities of Estelí and

Condega in October 2014. Farms selected were typical of smallholder farming systems in this region of the dry tropics – averaging under 5 hectares in size, based on basic grain production, and producing for the household or for local sale (Rodríguez et al. 2013). Five local organizations[28] that work with producers were asked to identify two areas in which they were active: one with more and one with less advanced implementation of agroecological practices. The organizations facilitated access to key informant farmers and the villages; in the villages, snowball sampling and 'spontaneous recruitment' (Peek and Fothergill 2009) were used to identify and recruit study participants.

The closed-question survey was divided into three parts: farm and household information; adoption and frequency of use of 28 agroecological practices (see Table 6); and, to explore participants' pro-environmental personal norms related to the adoption and use of agroecological practices, a section with questions based in social psychology (see Table 7). The survey questions followed this order. One qualitative question at the end gave participants an opportunity to give feedback on the survey, or to impart other information they felt was pertinent. Respondents were asked to indicate their agreements with questions relating to agroecological practices and statements relating to personal norms on a 5-point Likert scale (graded from 1: not important/not used to 5: very important/used a lot).

3.3.2 Procedure

A list of agroecological practices was compiled prior to conducting the survey. Initially based in a literature review (e.g. Altieri 2002; Altieri and Nicholls 2012; Wezel et al. 2014), the list of agroecological practices was refined to reflect practices in use in northern Nicaragua after preliminary discussions with our local research assistants and key informant farmers in the study area (see Table 6 for the final list of practices). Initially written in English, the survey was translated to Spanish by the lead researcher, edited for proper local usage by two Nicaraguan research assistants, and back-translated to ensure the questions were being asked in the correct format. The survey was pre-tested with nine key informant farmers from the study area and tweaked according to their input and for time management. The finalized survey was conducted, in Spanish and face-to-face in farmers' homes, by the two Nicaraguan research assistants; each survey took between 30 and 40 minutes to complete. Participants were informed of the background of the research they were being asked to become part of, assured of the anonymization of their data, and gave their written consent to participate in the survey. They were not remunerated for their participation.

[28] The organizations are Octupan, FEM, ASDENIC, Foro Miraflor, and PCAC-UNAG.

Table 6: Agroecological practices used in study area, clustered according to which agroecosystem process they most strongly support (following Altieri (2002))

Cluster of agroecological practices	Practices (as used in survey)
Recycling on-farm biomass / saving biomass	Contour lines, live barriers, hedgerows, conservation tillage, organic inputs, windbreaks, compost, recycling manure for use as fertilizer, bio-fertilizers, fallow, mulching
Biological pest & disease control	Integrated pest management, integrated disease management
Enhancing biological activity / interactions	Cover crops, legume cultivation, increasing soil biomass, enhancing soil microorganisms, using plants to attract beneficial insects, trap crops, soil inoculation with mycorrhiza
Saving on-farm water	Water harvesting, minimizing use of water, soil and water retention barriers, sources and methods used in irrigation
Enhancing biodiversity / diversifying genetic resources	Crop rotation, native seeds, agroforestry, companion planting

3.3.3 Measures

Participants were asked about their adoption and frequency of use of 28 agroecological practices (see Table 6). Because the survey asked about the adoption of agroecological practices on a scale of 1 to 5, according to how often the practice was used by farmers (1: never, 5: always), the data reflect not just the binary adoption yes/no, but a more nuanced view of each practice's frequency of use after adoption.

Pro-environmental personal norms were assessed using a 10-item scale, with statements based on Steg, Dreijerink, and Abrahamse (2005) and tailored to the current research context and list of practices. Table 7 details the statements used in the survey.

Table 7: List of items assessing farmers' pro-environmental personal norms in the survey (based on Steg, Dreijerink, and Abrahamse 2005)

I feel personally obliged to use more sustainable agricultural practices on my farm.
I feel guilty when I use chemical fertilizers and pesticides on my farm.
I feel personally obliged to recycle more on-farm biomass.
I feel personally obliged to use biological pest control methods on my farm.

I feel personally obliged to use biological disease control methods on my farm.
I feel personally obliged to save nutrients on my farm.
I feel personally obliged to save water on my farm.
I feel personally obliged to increase on-farm diversity.
I feel obliged to bear the environment and nature in mind in my daily behavior.
I would be a better person if I used agroecological farming practices.

3.3.4 Analysis

Survey responses were digitalized and analyzed using the software SPSS. We used descriptive statistics to characterize the prevalence of agroecological practices being used on the respondents' farms: this included both the adoption of each practice as well as how frequently it was used, based on the Likert scale rating from respondents. We tallied how many agroecological practices were used on each farm, and the average frequency of use of each practice across all farms. In a next step, we clustered the practices into five categories according to which ecosystem services are most enhanced by the particular technology, a common practice in agroecological theory (Altieri 2002); the practices in each cluster are detailed in Table 6. We explored these results according to age, gender, and years of agroecological experience of the respondent. As differences in the adoption and frequency of use of agroecological practices were the most defined according to the gender of the respondent, we targeted gender as a possible key explanatory variable. In the last step, we explored the relationship between personal norms and the adoption of agroecological practices and investigated whether this association differed between male and female farmers using first, a regression analysis and second, a simple slopes analysis to indicate interactions between gender and personal norms for the adoption of the different practices and clusters.

3.4 Results

3.4.1 Household and farm characteristics

Of the 119 survey participants, 69 (58%) were female and 50 were male (42%). Of the persons responding as the head of their household, 56% were female and 44% were male. Participants' ages ranged from 16 to 70 years old (M = 37, SD = 14.5). 118 of the 119 farmers self-identified as agroecological farmers. On average, farmers had been using agroecological practices for nine years (with answers ranging between 1 and 25 years, SD = 6). They had been farming on their land for an average of 15 years (ranging between 2 and 50 years, SD = 9.5).

Farm sizes ranged from 0.25 manzana[29] (mz) to 67 mz, but the mean of 5.17 mz (*SD* = 7.5) shows that larger farms are not that common. 76.9% of farmers grew maize and beans, the predominant local staple crops, and 44.6% grew coffee, the predominant local cash crop. Looking specifically at crop diversity, participants grew an average of 22 crops, with the most respondents (*N* = 16) growing 26 different crops (see Figure 13). In all, farmers reported that they produced 22 types of fruits, 14 types of vegetables, plus quinoa, cacao, sugar cane, and medicinal plants. 75% of farmers kept livestock, with chickens being the most prevalent, followed by cows, pigs, and horses. 40% of participants indicated that they had an area dedicated to forest, with areas ranging from 0.1 mz to 11.5 mz (*M* = 2.13 mz; *SD* = 2.48). Increasing farm size correlated positively with forest size (.782**, *p* = .000).

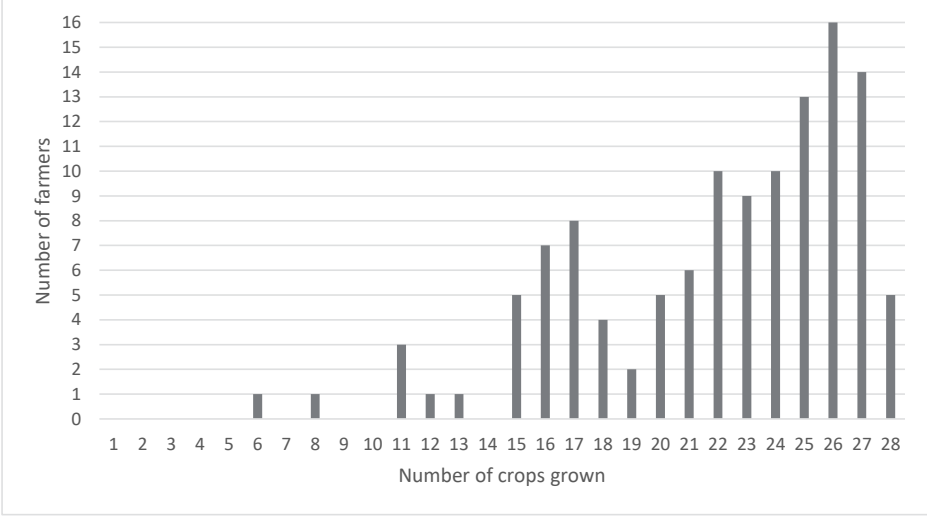


Figure 13: Number of crops grown by individual farmers (*N* = 119)

3.4.2 Adoption and frequency of use of agroecological practices according to gender

The first research question addressed differences in adoption patterns between male and female farmers. The results identified which agroecological practices are adopted by farmers and with which frequency they are being used, disaggregated by gender. We looked at four variables, disaggregated by gender: the total number of agroecological practices adopted, which agroecological practices are adopted, which agroecological practices are used the most frequently, and finally, the frequency with which clusters of agroecological practices are adopted.

[29] Manzana is the unit of land measurement used in Nicaragua. 1 manzana = 0.7044 hectare = 7,044 m^2.

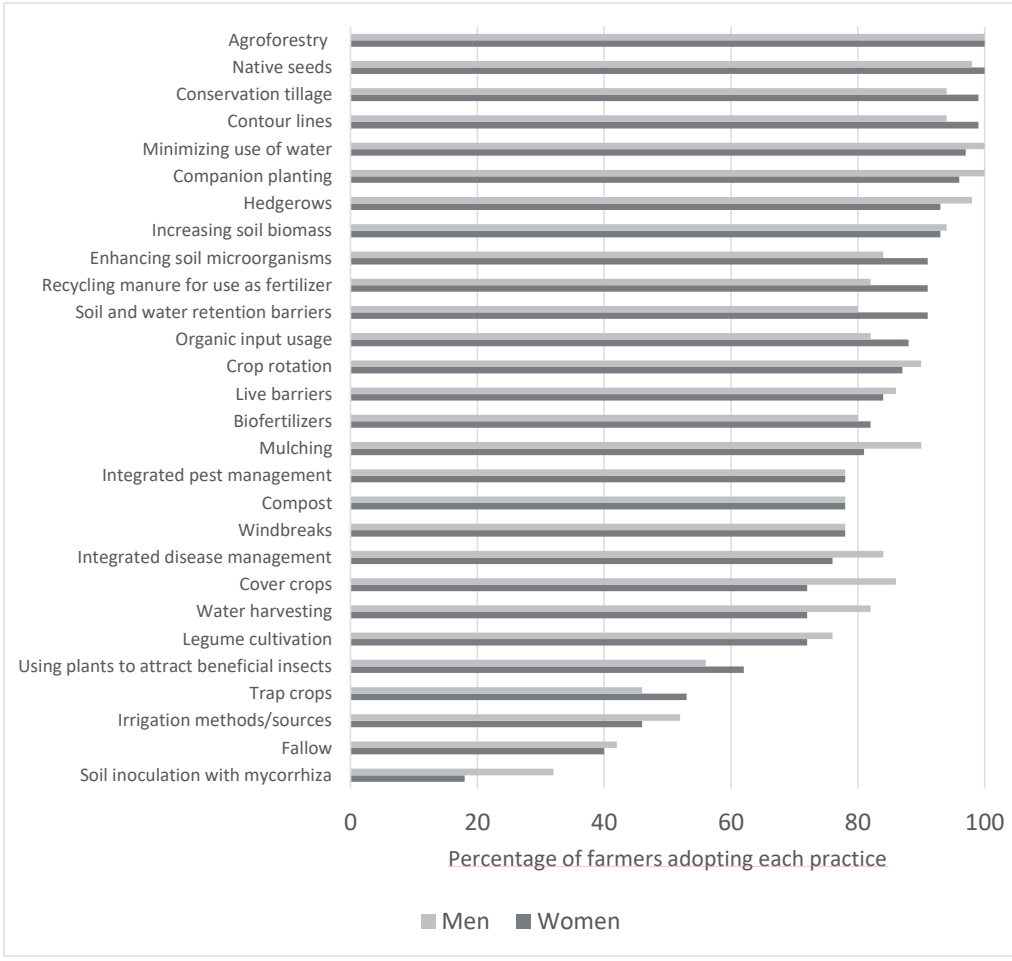


Figure 14: Practices adopted by farmers ($N = 119$), disaggregated by gender (men: $N = 50$; women: $N = 69$)

Both male and female farmers reported adopting an average of 25 practices, with the median for men (27) slightly higher than that for women (26). As can be seen in Figure 14, the adoption of practices follows similar patterns across both genders. Almost all farmers use agroforestry, or the planting of trees and shrubs. Most use native seeds for their crops and practice conservation tillage, use contour lines on hillsides, minimize the use of water, and use companion planting to increase yields. Significantly more women than men adopted the building of soil and water retention barriers, recycling manure for use as fertilizer, enhancing soil with microorganisms, using trap crops and using plants to attract beneficial insects. Practices adopted by significantly more male farmers than female farmers include the use of cover crops, water harvesting, mulching, integrated disease management, and inoculating soil with mycorrhiza. The latter practice also showed the greatest difference between male and female adopters, with almost twice as many men as women adopting the inoculation of soil with mycorrhiza.

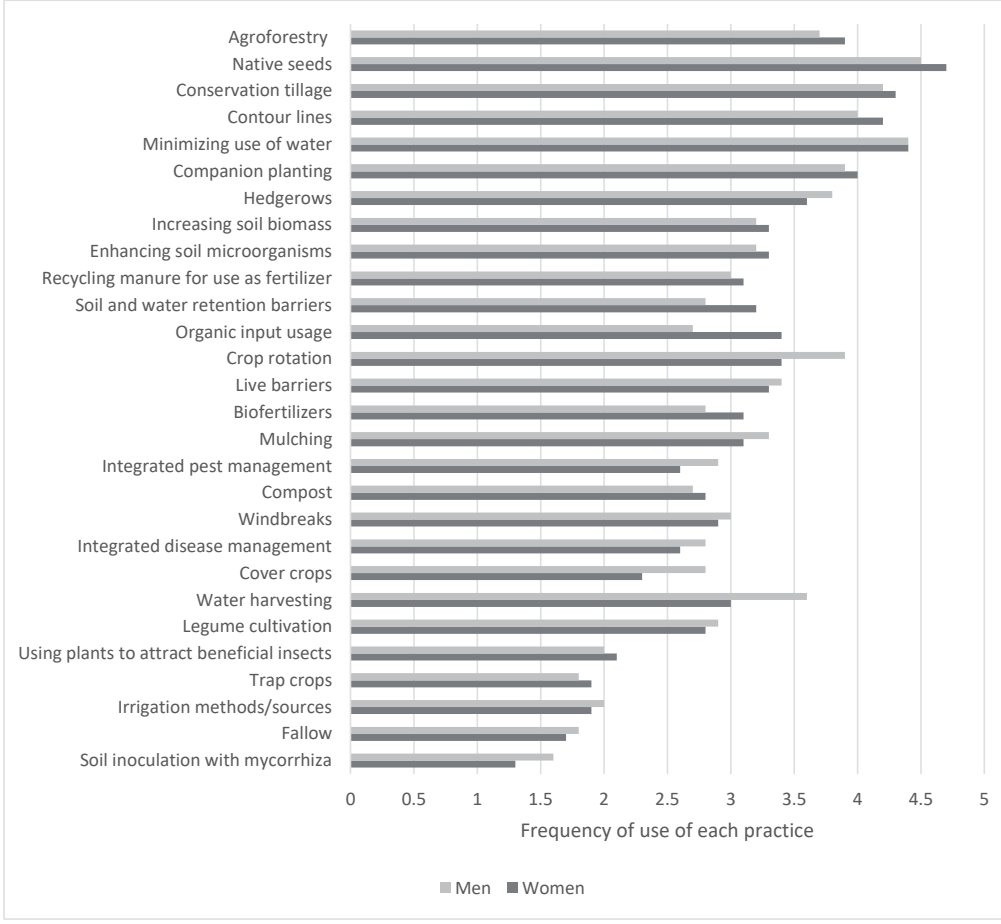


Figure 15: Female and male farmers' frequency of use of each agroecological practice (N = 119), disaggregated by gender (men: N = 50; women: N = 69)

Results of the frequency of use of the practices follow similar trends. In Figure 15, each practice's frequency of use is listed according to its ranking in Figure 14, which depicts the percentage of farmers of each gender who adopted each practice. Mirroring Figure 14, practices used most frequently by both men and women are the use of native seeds, minimizing the use of water, conservation tillage, and contour lines. Male farmers use the practices of water harvesting and crop rotation much more frequently than female farmers, while female farmers more frequently build soil and water retention barriers and use organic inputs.

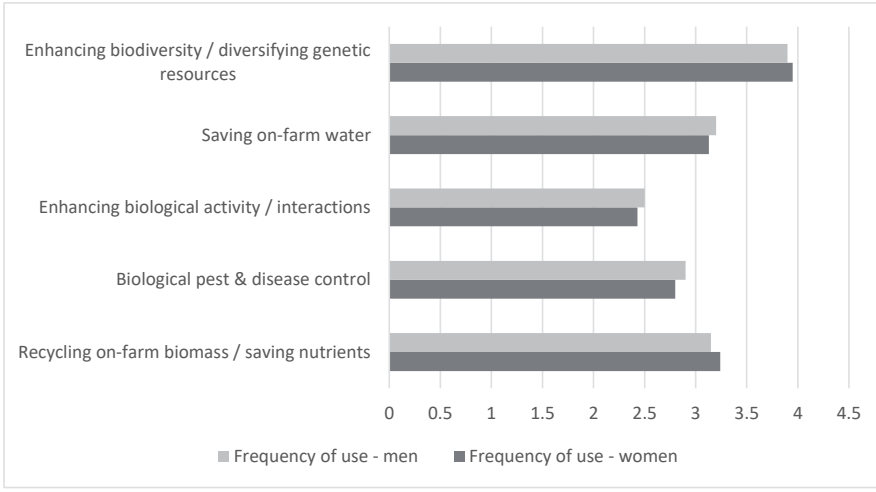


Figure 16: Frequency of use of clusters of agroecological practices by gender (N = 119; men: N = 50, women: N = 69)

Clustering the practices according to the ecosystem services they provide, the set of practices relating to enhancing biodiversity and diversifying genetic resources is applied most frequently, by both male and female farmers, of the agroecological clusters (Figure 16). This is due to the strong frequency of use of native seeds and agroforestry, as shown in Figure 15. The cluster least frequently applied by both male and female farmers, enhancing biological activity and interactions, includes the infrequently used practices of soil inoculation with mycorrhiza, trap crops, and using plants to attract beneficial insects.

3.4.3 Do female and male farmers' pro-environmental personal norms affect their adoption of agroecological practices?

The second research question investigates the relationship between female and male farmer's pro-environmental personal norms and their adoption of agroecological practices. The survey results suggest that the strength of farmers' pro-environmental personal norms does predict their adoption of agroecological practices – and that this association is qualified by the farmer's gender. Figure 17 shows the relationship between the strength of female and male farmer's pro-environmental personal norms and the frequency of use of all the agroecological practices listed in the survey. As the figure illustrates, male farmers' adoption of agroecological practices shows a positive correlation with the strength of their pro-environmental personal norms: male farmers with stronger pro-environmental personal norms tend to adopt agroecological practices more intensively. For female farmers, this positive correlation between does not exist, and in fact is slightly negative: they adopt agroecological practices at a relatively steady rate, regardless of the strength of their personal norms. This means that when female farmers had lower pro-environmental personal norms, they still adopted agroecological practices at a stronger rate than did

male farmers with low pro-environmental personal norms. However, male farmers with high personal pro-environmental personal norms adopted agroecological practices at a stronger rate than did female farmers with high pro-environmental personal norms.

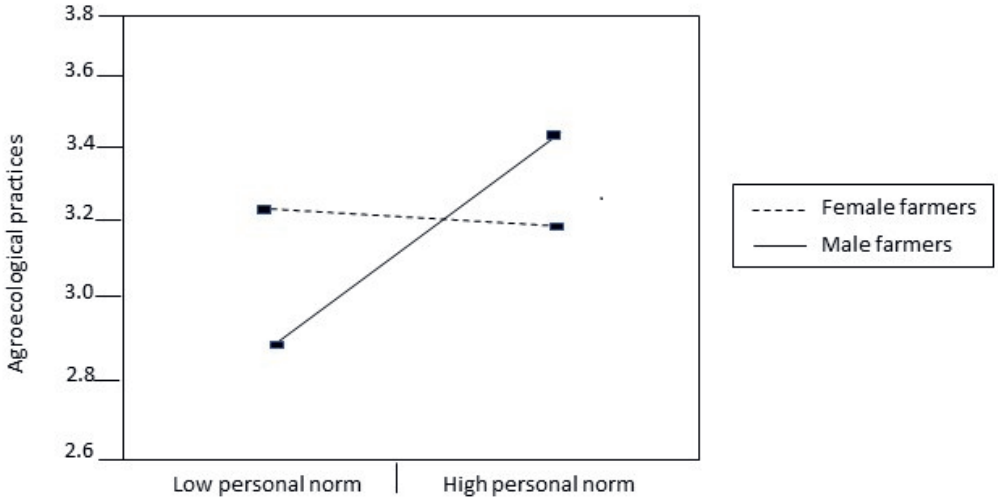


Figure 17: Frequency use of all agroecological practices, based on the strength of the farmer's pro-environmental personal norms

Turning to the five clusters of practices more closely, we investigated the effects of gender and personal norms on the adoption of practices in each cluster. Looking at interactions between gender and pro-environmental personal norms for each of the five clusters of practices, we found significant interactions in the clusters 'enhancing biological activity/interactions' and 'recycling on-farm biomass/saving nutrients' (see Table 8 and Table 9).

Table 8: Main results of gender, personal norms, and the interaction between gender and personal norms (PN) on the adoption of agroecological practices (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$; ****: $p < 0.0001$)

	PN	Gender	PN x Gender Interaction
All practices	.416**	1.883**	-.403**
Recycling on-farm biomass/Saving nutrients	.382*	2.193**	-.459**
Biological pest & disease control	.105	1.858	-.397
Enhancing biological activity/ Interactions	.465*	2.009*	-.436*

	PN	Gender	PN x Gender Interaction
Saving on-farm water	.621*	.903	-.203
Enhancing biodiversity/ Diversifying genetic resources	.644****	1.134	-.239

Both female and male farmers reported strong adoption frequencies of the practices in the cluster 'enhancing biological activity and interactions'. While the strength of male farmers' pro-environmental personal norms correlates positively with their adoption and intensity of use of this group of agroecological practices, the strength of female farmers' pro-environmental personal norms did not show effects on their adoption of this group of practices, even slightly declining (see Figure 18). The cluster 'recycling on-farm biomass and saving nutrients' relates to conserving resources on the farm, e.g. through soil and water conservation practices. In this practice cluster, male farmers' pro-environmental personal norms again correlate positively with their intensity of use: the higher male farmers' pro-environmental personal norms, the higher their intensity of use of these practices. Interestingly, while female farmers used agroecological practices intensively even with low pro-environmental personal norms, in this cluster their practice use intensity slightly declined with higher pro-environmental personal norms.

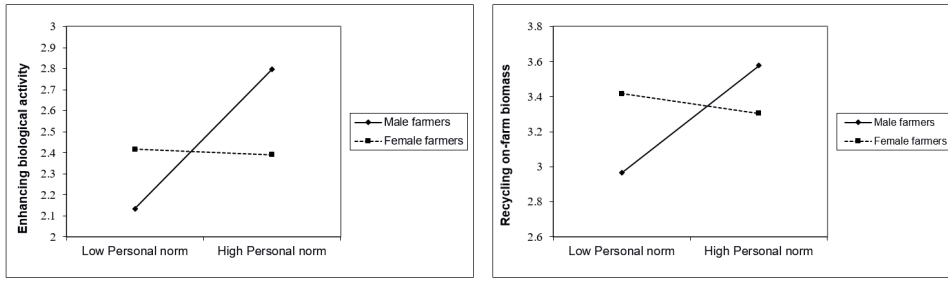


Figure 18: Interactions between gender and personal norms for the practice clusters 'recycling on-farm biomass/saving nutrients' and 'enhancing biological activity and interactions'

To conclude, our analysis suggests that personal norms predict adoption of agroecological practices, but that this association is qualified by the farmers' gender. Hence, the hypothesis set out in the introduction - farmers with stronger pro-environmental personal norms adopt more agroecological practices, regardless of their gender - was proven false by the results. Only male farmers with higher pro-environmental personal norms adopted agroecological practices more frequently. Female farmers'

adoption of agroecological practices remained steady, even slightly declining, with higher pro-environmental personal norms.

Table 9: Significance of interactions between personal norms and gender on three outcome variables: all practices together, and the clusters 'enhancing biological activity' and 'recycling on-farm biomass'

	Female farmers	**Male farmers**
All practices		
Gradient (β)	0.013	0.819
t-value	0.254	9.980
p-value	0.799	0.000
Cluster: Enhancing biological activity and interactions		
Gradient (β)	-0.292	0.502
t-value	-5.715	6.117
p-value	0.000	0.000
Cluster: Recycling on-farm biomass and saving nutrients		
Gradient (β)	-0.077	0.841
t-value	-1.507	10.248
p-value	0.132	0.000

3.5 Discussion

The results showed that the farmers in the case study, both female and male, grow a diversity of crops and use a diversity of agroecological practices to do so. Which practices are adopted, and how frequently they are used, follows largely the same pattern for female and male farmers. Practices related to enhancing biodiversity - the use of native seeds, crop rotations, companion planting, and agroforestry - were both adopted by the most farmers and used the most frequently by farmers of both genders. These practices link to farmers' framework conditions in northern Nicaragua: companion planting of the 'milpa' trifecta of beans, squash, and maize has been practiced for thousands of years in Central America, and coffee, the local cash crop, is often grown under shade trees. Seed banks for native varietals, organized by a variety of government and non-state entities, have proliferated in the past decade.

Further, the analysis indicated that although a farmer's pro-environmental personal norms predict the adoption of agroecological practices, this association is qualified by the farmer's gender. For the personal norms literature, this implies that further research is needed on this link between gender and

personal norms, and to what extent pro-environmental behavior is moderated through gender. Particularly the slightly negative correlation between female farmers' pro-environmental personal norms and their adoption of agroecological practices warrants further investigation. Further research from a socio-psychological perspective could explore the differences between men and women's actions stemming from their pro-environmental personal norms, and interactions between the variables identified in this study.

The agroecological scientific literature recognizes that dimensions of gender intersect with those of e.g. age, class and caste, religion, health, and race in contributing to dynamics of marginalization and inequity (Anderson et al. 2021). Yet, agroecology does not explicitly address gender-based inequalities, and much agroecology work has not (yet) incorporated an explicit gender analysis (de Marco Larrauri, Pérez Neira, and Soler Montiel 2016). The results suggest that gender should be taken into account when planning agroecological work, such as agricultural extension or programs, in order to better focus activities and learning on topics that are relevant to different groups. This points to three issues: the need to include stakeholders of both genders in agenda-setting and planning; the need for deliberate, contextualized actions; and the need of designing of appropriate interventions, including innovative, gender-transformative practices and intervention options (Kristjanson et al. 2017). While affirming and protecting women's work and insights is important to support agroecological transitions, it is also important that this does not become a way to reify gendered differences in roles and knowledge, which may often add to women's workloads (Anderson et al. 2021). Instead, agroecology's emancipatory potential should be exploited to increase the fluidity of gender roles, e.g. through focusing on learning and knowledge-sharing to create spaces for women to gain livelihoods, income, and agency (Khadse 2017; Anderson et al. 2021).

Further practical implications of the results suggest that, to grow the adoption of pro-environmental practices, it would be important to focus on increasing male farmers' pro-environmental attitudes through e.g. increasing knowledge about the importance of environmental protection and conservation (Caron, Biénabe, and Hainzelin 2014; Duru et al. 2015). Considering female farmers, a more nuanced understanding of other, non-socio-psychological factors that influence their decision-making to adopt pro-environmental practices, such as agroecology, is necessary to better underpin programs aiming to support women in transitioning to more sustainable forms of agriculture. Stronger policy and deliberate programmatic support for broader processes of social learning could be another interesting avenue to increase individuals' pro-environmental values and intentions (Noguera-Méndez, Molera, and Semitiel-García 2016). The results point to the importance of gender-informed research and practice for better climate change adaptation and environmental management (Jerneck 2018). The inclusion of socio-psychological variables into research on farmers' decision-making is particularly relevant for both policy and practice for two reasons: agroecology is often not adopted for financial reasons, as subsidies are scarce or nonexistent and agroecological products usually don't command a price premium in markets;

and motivational factors play a crucial role particularly for the smallest and poorest farmers (Delaroche 2020).

3.6 Conclusion

In this paper, we first examined similarities and differences between female and male farmers' adoption and frequency of use of agroecological practices, before using a social-psychological approach to explore the relationship between farmers' pro-environmental personal norms and their adoption of agroecological practices. We found that both female and male farmers adopted a high number of agroecological practices, with similar adoption rates and frequency of use patterns for most practices. The case study showed that the relationship between farmers' pro-environmental personal norms and their adoption of agroecological practices is mediated by their gender: female farmers' adoption of agroecological practices was less influenced by the strength of their pro-environmental personal norms, whereas male farmers' adoption of agroecological practices increased with higher pro-environmental personal norms. The findings highlight the importance of taking into account subjective aspects of individuals' decision-making that underpin their agency in enacting pro-environmental behaviors. Understanding individuals' motivations to themselves enact pro-environmental behavior could aid in connecting individuals' psychology to the larger social changes necessary to implement broader transitions to sustainability (Upham et al. 2018).

The findings beg the question: if female farmers are not strongly influenced by their pro-environmental personal norms to adopt agroecological practices, what motivates them? Future research should take into account also structural and relational conditions, which could be captured using a mixed-methods approach incorporating qualitative research. Such follow-up research could elaborate on the presented findings, and shed stronger light on other issues motivating (female) farmers to adopt agroecological practices. A stronger inclusion of questions related to gender, and beyond that, intersectional issues, in agroecological theory and practice may aid in uncovering hidden, implicit issues related to power and inequities, both systemically and in daily life, which can then be addressed. A more nuanced understanding of what drives female and male farmers to adopt agroecological practices, considering both contextual and socio-psychological aspects, can help inform agricultural policies and programs aiming to support transitions to sustainable agri-food production.

Chapter 4: Exploring barriers to the agroecological transition in Nicaragua: A Technological Innovation Systems approach

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Abstract

Latin America has historically been a vanguard of agroecology. In Nicaragua, an agroecological transition is occurring, with three decades of building a groundswell based on the farmer-to-farmer movement and the recent institutionalization of agroecology in national law. Yet, problems remain with agroecology's diffusion. We introduce the Technological Innovation Systems approach to examine systemic barriers to the agroecological transition and cycles of blockages caused by barriers' interactions. Based on qualitative data from north-central Nicaragua, we find the main barriers hindering the agroecological transition include weak guidance of the search for agroecology, insufficient capacities and quantities of resources, and lacking market development. Beyond the Nicaragua case, the analysis points at the importance of using socio-technical systems analysis to better understand and address the root causes behind issues blocking national agroecological transitions.

Keywords

Sustainability transitions; socio-technical systems analysis; Latin America; agroecology; agricultural innovation systems

4.1 Introduction

Agroecological farming systems, which utilize ecological principles for the design and management of resilient, sustainable, and productive farms, have been identified as promising alternatives to the dominant input-intensive agro-industrial production model (FAO 2015). While agroecology started as a grassroots movement (Altieri and Nicholls 2012), and its initial push came from social movements (Tittonell et al. 2016), it has increasingly become part of national policies (González de Molina 2013; Gliessman 2017). Agroecology's institutionalization in national policies of some countries can be seen as a next step in the transition of the agri-food system to more sustainable modes of production and consumption (Bacon et al. 2014), also referred to as the agroecological transition (Duru, Therond, and Fares 2015; McCune et al. 2016; Meek 2016; Ingram 2017; Teixeira et al. 2018; Ollivier et al. 2018).

Particularly in Latin America, "the expansion of agroecology […] initiated an interesting process of cognitive, technological, and socio-political innovation […] Thus, a new agroecological scientific and technological paradigm is being built in constant reciprocity with social movements and political process" (Altieri and Nicholls 2017, 235). This has led to great scholarly interest in processes of agroecological transition in Latin American countries, as evidenced by this journal's 2017 Special Edition (Gliessman 2017). The agroecological transition is a complex, multi-level process involving interactions and co-evolutionary alignments between the focal technology – agroecology – and associated bio-physical, social, political, economic, and institutional aspects (Piraux et al. 2010; Blesh and Wolf 2014; Pant 2016; Gaitán-Cremaschi et al. 2019). Hence, the agroecological transition may be described as the formation and development of a new agroecological innovation system within the dominant incumbent agricultural innovation system (based in conventional agriculture).

While authors have identified separate technological, political, and financial lock-in factors that may support or hinder the agroecological transition, such as a lack of knowledge about, political will to push for, or financing opportunities to support agroecology (Altieri and Nicholls 2008; Altieri, Nicholls, and Funes-Monzote 2012; Wibbelmann et al. 2013; Silici 2014), there is only limited analysis on how these factors interact. This paper addresses this gap by analyzing the development of the agroecological system in Nicaragua through the lens of technological innovation systems (TIS), defined as "a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology" (Markard and Truffer 2008, 611).

TIS analysis has been applied to explain the development of new technologies and the obstacles they face in transforming incumbent systems in the development and diffusion of sustainable innovations. Focusing on environmental sustainability, TIS analysis was originally applied to new energy technologies (Musiolik and Markard 2011; Wieczorek et al. 2013; Blum, Bening, and Schmidt 2015). It has been used in the agricultural context to analyze precision agriculture technologies (Eastwood, Chapman, and Paine 2012; Garb and Friedlander 2014; Busse et al. 2015), innovations in

the dairy sector in Ethiopia (Kebebe et al. 2015), the mycorrhiza value chain in France (Angeon and Chave 2014), and rainwater harvesting techniques in Jordan (Sixt, Klerkx, and Griffin 2018). Recently, the agroecological transition in Rwandan agriculture was analyzed using a socio-technical systems lens (Isgren and Ness 2017); related transition management theories have been used to explore the Nepalese agricultural sustainability transition (Pant et al. 2014).

In this article, we use TIS analysis to go beyond a description of the development of agroecology in Nicaragua. We identify factors supporting or limiting the agroecological transition and interactions between factors that create vicious cycles, further blocking the diffusion of agroecology. Nicaragua is especially pertinent for this analysis because agroecology has a long history in the country, has recently been enshrined in national law, and may be considered in a diffusion stage. The next section introduces the theoretical framework and some reflections on applying TIS analyses in the context of agroecology. Section 4.3 details methods and section 4.4 provides results of the structural-functional TIS analysis of Nicaragua's agroecological transition. Conclusions and contributions to literature are drawn in section 4.5, and section 4.6 presents a final discussion that reflects on the utility of TIS analyses to furthering our understanding of agroecological transitions.

4.2 Analytical framework: Technological Innovation Systems

In recent years, the TIS approach has become a useful tool for creating a holistic understanding of actors and institutions involved in the propagation of innovations (Birner 2012). At the national level, an agricultural innovation system consists of all actors, institutions, and policy settings concerning agricultural production and consumption. As a TIS, the agroecological innovation system (AeIS) is a subset of the national agricultural innovation system. It is composed of the actors, institutions, and policies involved in agroecology. Although this study examines Nicaragua's national AeIS, it is important to note that some national agroecological organizations are linked to the global agroecology movement, and as such form part of the global AeIS (in line with ideas of TIS crossing national boundaries (Hekkert et al. 2007)). The following section explains how structural-functional TIS analysis of the AeIS works.

4.2.1 A structural-functional analysis to give new insights on the agroecological transition

Innovation systems analysis distinguishes structures, i.e. the elements that make up the system, and functions, i.e. how these elements work in support of the innovation (Wieczorek and Hekkert 2012). The structures of an AeIS can be delineated as actors, institutions, interactions, and infrastructures and are described in Table 10.

Table 10: Structures of Technological Innovation Systems (based on Wieczorek and Hekkert (2012))

Structure	Description
Actors	The "players in the game" (Klein Woolthuis, Lankhuizen, and Gilsing 2005). Includes individuals and organizations, such as farmers, farmer organizations, civil society organizations, government agencies, knowledge and research institutes, financial organizations, and donor organizations.
Institutions	The "rules of the game". Can be hard (formal institutions, such as policies, standards, and regulations) or soft (informal). Institutions can support innovation processes by enabling space for change, or conversely hinder it through rigidity and close-mindedness.
Interactions	Interactions can help actors e.g. align their visions, leverage resources, and share knowledge. Includes informal interactions between actors or institutions, and formalized interactions such as networks.
Infrastructures	Includes physical infrastructures (e.g. roads, structures, networks, machines, artefacts), financial infrastructures (e.g. subsidies, specific credit lines, financial programs) and knowledge infrastructures (e.g., knowledge, strategic information).

To identify issues that hinder the diffusion of agroecology, an innovation systems approach analyzes the way these structures enable innovation in support of a transition towards agroecology by examining the performance of so-called "functions of the innovation system". Seven key functions have been identified in the literature and are explained in Table 11.

Table 11: Functions and diagnostic questions for systemic analysis (Hekkert et al. 2007; Bergek, Jacobsson, and Sandén 2008; Wieczorek and Hekkert 2012; Wieczorek et al. 2013)

Function	Description	Diagnostic questions
F1: Experimentation by entrepreneurs	Entrepreneurs are essential: their role is to turn the potential of new knowledge, networks and markets into concrete actions to generate and take advantage of business opportunities. Experimentation by entrepreneurs refers to not just actors' willingness to experiment with the new technology, but also their ability to do so – which is based on the resources at their disposal. Different types of actors experiment differently: for example, farmers may experiment with agroecological practices on their farm, while market entrepreneurs may experiment with novel value chain arrangements.	Sufficient and suitable actors contributing to diffusion? Amount and type of experiments sufficient?
F2: Knowledge development	Mechanisms of learning are at the heart of any innovation process. Knowledge development involves both experimentation (learning-by-doing) and research (learning-by-searching) (van Mierlo et al. 2010). New knowledge can be created by e.g., farmers through farm experimentation, or in formalized institutional settings such as	Enough and competent actors involved in knowledge development? Knowledge development

Function	Description	Diagnostic questions
	universities, and further serves to legitimize the use of agroecology.	sufficiently aligned with actors' needs?
F3: Knowledge exchange	Knowledge exchange is the co-construction of knowledge by actors from different sectors of the TIS, as well as the formalization of knowledge exchange processes (e.g., through networks).	Sufficient networks or connections through which knowledge is exchanged?
F4: Guidance of the search	The processes that lead to a clear development goal for the new technology based on technological expectations, articulated user demand and societal discourse. Guidance of the search is the creation of a clear vision for further development of the technology and involves an understanding of different actors' goals and visions. It is an important factor in aligning actors' visions of how the system is functioning, and how it should move forward. In countries with a centralized political system (such as Nicaragua), this function is heavily dependent on government input.	Do actors and institutions provide sufficiently clear direction for future development?
F5: Market formation	Market formation entails the use of a variety of mechanisms to create demand for the outputs of the new technology (Sixt, Klerkx, and Griffin 2018) – here, agroecological products. The creation of markets facilitates cost reductions and incentivizes entrepreneurs.	Size of market sufficient to sustain entrepreneurial experimentation and innovation?
F6: Resource mobilization	Resource mobilization – of financial and human resources, knowledge and physical resources – is necessary for TIS growth and intimately linked to actors' alignment along similar goals and their shared visions. New technologies, particularly knowledge-intensive technologies such as agroecology, often have difficulties competing with entrenched technologies (Hekkert et al. 2007).	Sufficient financial resources? Sufficient and competent actors? Sufficient physical infrastructure?
F7: Creation of legitimacy	Innovation is by definition uncertain. The creation of legitimacy reduces uncertainties and counteracts the resistance to change. The creation of legitimacy for agroecology vis-à-vis the dominant conventional agricultural system is of central importance to further diffuse agroecological practices and principles nationwide by securing broad (public) support for agroecology. It helps minimize uncertainties to which actors are exposed, e.g. through supporting market development or enabling a stable regulatory environment (Klerkx, Aarts, and Leeuwis 2010).	Do actors, formal and informal institutions sufficiently contribute to legitimacy? How much external resistance is present towards the technology?

Further, systemic problems may have causal relationships and form clusters of so-called blocking mechanisms. These blocking mechanisms may reinforce each other, leading to "vicious cycles" of

problems that hinder the further diffusion of agroecology (Klein Woolthuis, Lankhuizen, and Gilsing 2005; Weber and Rohracher 2012). The coupled functional-structural analysis identifies these barriers and aids in pinpointing entry points to support the diffusion of agroecology (Lamprinopoulou et al. 2014; Kebebe et al. 2015). Systemic problems are related to the presence (or absence) and quality (or capacity) of each of the structures in contributing to each of the functions (see Table 12) (Wieczorek and Hekkert 2012).

Table 12: Systemic problems leading to blocking mechanisms (based on Wieczorek and Hekkert (2012))

Problem dimension	**Actors**	**Institutions**	**Interactions**	**Infrastructures**
Presence or absence	Absence of actors	Absence of specific institutions that support the agroecological transition	Missing interactions due to e.g. lacking trust, capacities, differing assumptions	Absence of necessary infrastructures, such as value chains or knowledge exchange
Quality / Capacity	Lacking capacity of actors	Strong institutional problems leading to technological 'lock-in' of conventional agriculture; weak institutional problems hinder innovation concerning agroecology	Strong network problems exist when some actors are erroneously guided by stronger actors; weak network problems hinder interaction and innovation	Lacking quality of infrastructures, e.g. bad roads hindering timely access to markets

4.3 Methodology

This research is a qualitative case study analysis of agroecology in Nicaragua. Results are based on fieldwork conducted in northern and central Nicaragua undertaken in 2014 and 2016-18. All fieldwork, including interviews, workshops, and document analysis, was conducted in Nicaragua's official language, Spanish. Table 13 summarizes the fieldwork events and participants.

A review of scientific and grey literature preceded and accompanied the field study and results analysis period. This data included national policy documents (e.g. GRUN 2011; 2012); newspaper articles (e.g. Herrera 2014); reports from international donors, research centers, civil society organizations, and non-governmental organizations (e.g. Fundación Luciérnaga and SIMAS 2010; Fréguin-Gresh 2017a); and peer-reviewed articles on agroecology in Nicaragua (e.g. Godek 2015; Gonzálvez, Salmerón, and Zamora 2015; McCune 2016; McCune et al. 2016). Scientific literature was found using keyword searches that reflected the different aspects of this paper: the term 'agroecology' or 'agroecological' in combination with 'Nicaragua', 'technological innovation systems', 'adoption', 'scaling', or 'transition'.

The searches were performed in the scientific literature databases SCOPUS, ScienceDirect, Web of Science, and Google Scholar.

Table 13: Summary of data collection

Type of data gathering	**Details – respondents from organizations**
Semi-structured interviews (2014 and 2018)	4 scientists and extensionists from producer organizations 6 scientists from research and education institutes 2 department managers from government institutions 2 managers from financial institutions 1 scientist from INGO 3 scientists from national NGOs 9 agroecological smallholders
Workshops (2014 and 2016)	2 with agroecological smallholders, total: 27 participants (11 female, 16 male) 1 multi-stakeholder, 8 participants
Farm visits and interviews (2014 and 2016)	9 agroecological smallholders (3 female, 6 male)
Literature review (2014-2018)	Scientific literature Grey literature from involved organizations Newspaper articles
Document analysis (2014-2018)	Government policies Internal documents from involved organizations

To understand the agroecological transition from different perspectives – its implementation at the national (political) level and the rural (farm) level – data was gathered during research in Managua, the capital, and in three rural areas, shown in Figure 1. The rural locations were chosen to represent a variety of agroecological zones (the dry tropics in Estelí and the humid tropics in Jinotega and Waslala) and cropping systems (mixed basic grains and livestock in Estelí, coffee-based systems in Jinotega, and cocoa-based systems in Waslala). Additionally, each area had the presence of an active Territorial Learning Alliances (TLA, also called innovation platforms in the broader literature (Kilelu, Klerkx, and Leeuwis 2013b; Schut et al. 2018)) promoting agroecology. To capture as rich a picture as possible, targeted research participants included stakeholders from a variety of groups: agroecological farmers and farmer organizations, national-level and local-level CSOs, NGOs, research institutes, educational institutes, and government institutions. Semi-structured interviews were conducted with organizations that work on "bigger picture issues" (e.g. knowledge-sharing or national development programs) in Managua. These interviewees acted as informants (describing the bigger picture and observations from a position as a scientific expert or a policy formulator). Participating organizations were first identified based on a preliminary literature review. The interviews with representatives from organizations then provided input on whom else to interview. Interview topics covered included how agroecology developed in Nicaragua, the organization's goals concerning agroecology, its role in supporting

agroecology, whom it networks or partners with, what kind of projects it undertakes, and what challenges it has faced in supporting agroecology.

To gain a detailed understanding of what smallholder agroecological farms may look like in different agroecological zones (Evans and Jones 2011), interpretive farm walks were held with farmers around Jinotega, Waslala, and Estelí (see Figure 19). Participatory workshops were held in the region around Estelí because it best represented smallholder farming systems around the country (e.g. farmers with cropping systems based on basic grains and livestock production for national consumption and not on (export) cash crops such as cocoa or coffee). Two kinds of workshops were held: one with farmers and one with representatives of local CSOs and farmer organizations. Participants of both workshops were identified through their membership in one of five local organizations who were members of the TLA. To strengthen the validity of the data gathered in the workshops, we aimed to capture the opinions of male and female farmers from a broad range of ages. Farmers acted as respondents, detailing their direct experiences with agroecology. The organizations facilitated initial contact with lead farmers in villages around Estelí. The lead farmers suggested other male, female, and youth farmers who might be interested in participating in the workshops, whom we contacted and invited to participate. The organizations also put out a broad invitation to all members to join the workshops. During the workshops with farmers, participants reflected on what 'agroecology' and 'being an agroecological farmer' meant to them, drew rich pictures of how their farms currently look and how they would look if they corresponded fully to the farmer's ideal of an agroecological farm, and discussed challenges that prevented them from realizing their ideals of a fully agroecological farm. During the workshops with representatives of local organizations, participants presented their organization's definition of agroecology, its goals in supporting agroecology, with whom and how it works to support agroecology, reflected on the challenges it faces in achieving its goals, and identified what steps it would need to undertake in the near and medium future to achieve these goals. Further, they discussed what kind of an environment they would need – outside of their organization – to be able to work more effectively in supporting farmers to produce agroecologically. To deepen ideas touched upon during the workshops, semi-structured interviews were held with several farmers and organizations. With the interviewee's permission, the interviews were recorded. A Nicaraguan assistant later transcribed them. To identify themes emerging from the data, the transcriptions were coded in an ongoing process based on the grounded theory principles of objectivity and reflexivity (Strauss and Corbin 1990; Timonen, Foley, and Conlon 2018). Because research participants acted both as respondents (detailing their personal experiences) and informants (describing the bigger picture), thick data to be gathered on not only organizational issues, but also on personal experiences from those supporting the agroecological transition in Nicaragua.

We used an event history analysis to explore AeIS development over time, mapping the interactions between structural elements and system functions to analyze the main events in the development of the AeIS (Hekkert et al. 2007; Bergek et al. 2008; Hekkert and Negro 2009; Kebebe et al. 2015). The event history analysis focused on the development of the AeIS since 2007 since that is when the agroecological

sector in Nicaragua can be said to have entered a phase of expansion. The event history timeline was first constructed based on the literature and document review and then validated and enrichened with data gathered from interviews and workshops. The data from interviews and workshops was further analyzed to unravel the enactment and performance of the seven functions of TIS. Due to the dynamic characteristics of the AeIS' development, the results present an interpretative punctual approximation of the development of agroecology in Nicaragua.

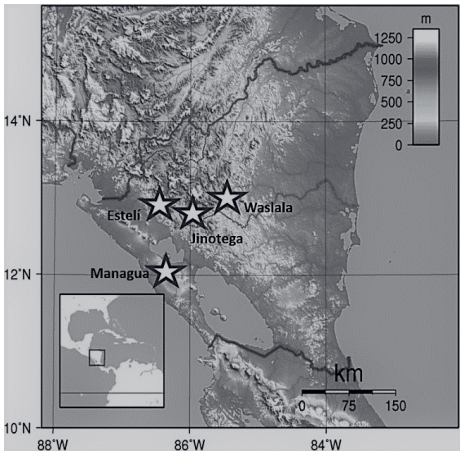

Figure 19: Map of Nicaragua with research areas starred (mapsof.net 2014)

4.4 Results

4.4.1 Development of the agroecological innovation system

The growth of the AeIS in Nicaragua can be divided into three phases, with developments in each phase strongly influenced by the ideology of the party in power (see Figure 20). The roots of agroecology lie in the Nicaraguan Revolution, which culminated in 1979 with the triumph of the popular revolution led by the Sandinista National Liberation Front (FSLN). Agroecology was introduced in Nicaragua in 1987, when the National Union of Farmers and Ranchers (UNAG) invited the Mexican Campesino a Campesino (farmer-to-farmer) movement to Nicaragua as part of a soil and water conservation program. There has been a marked increase in agroecological activity since the re-election of the FSLN in 2006. During the neoliberal regime of the 1990s, as state involvement was rolled back, non-governmental organizations (NGOs) proliferated. Agroecology continued to be spread by CSOs, NGOs, and local farmer organizations, but little happened at the level of government. Hence, we identify three periods in the development of the AeIS: the FSLN's Revolutionary rule from 1979-1990; the neoliberal regime from 1990-2006; and the current Government of Reconciliation and National Unity (GRUN), headed

by the FSLN since 2006. Figure 20 shows a timeline of these three phases. The subsequent analysis focuses on the period since 2006, when agroecology entered a phase of broader diffusion.

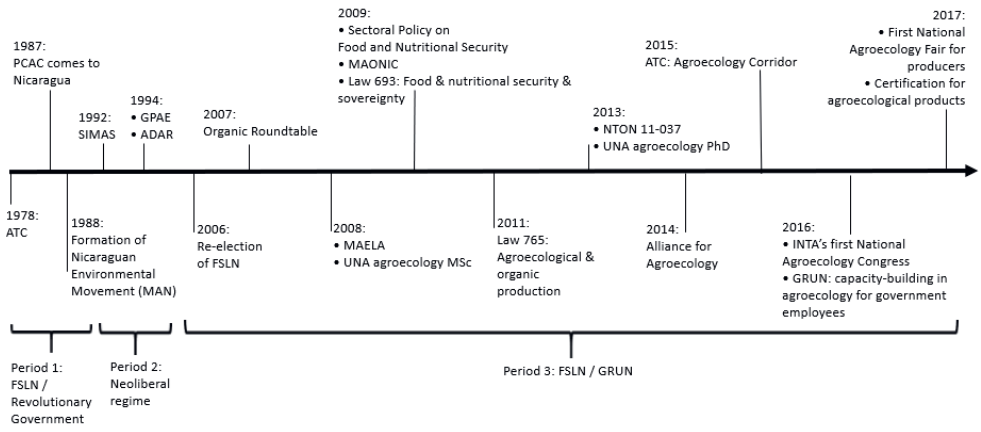

Figure 20: Timeline of the three periods of the agroecological innovation system in Nicaragua, with main events of each period

4.4.2 Recent developments: The AeIS since 2006

Since 2006, the agroecological transition has caught new headwind; the GRUN took a lead role in enacting national policies favorable to agroecology, and numbers of agroecology-minded platforms and networks increased. The GRUN re-oriented government policy to position the FSLN's Revolutionary ideal of self-sufficiency as central to equitable and rapid development (Godek 2015). Hence, the 2009 Sectoral Policy on Food and Nutritional Security and Sovereignty, part of the government's National Plan for Human Development, explicitly links national food security to agroecology in multiple government arenas like environmental conservation and public health (Herrera 2014). The national discourse on agroecology has widened to include e.g. broader environmental and ecosystem conservation goals, gender equality for women, youth, and other disadvantaged groups; CSOs have taken an active role in shaping national policy (Godek 2013; Boone and Taylor 2016; Fréguin-Gresh 2017a). In 2011, the GRUN passed Law 765, the Agroecological and Organic Production Law. Formal interactions between organizations at the national level has taken off since 2007, with organizations promoting (agro)ecological farming practices joining together in umbrella organizations and networks.

4.4.3 Structural - functional analysis of systemic problems in the development of the AeIS

Focused on the broader diffusion of agroecology since 2006, this sub-section analyzes the seven functions of the AeIS presented in Table 2 above. First, factors that impede the functioning of the AeIS

are identified; next, systemic problems hindering its growth are highlighted. These factors are summarized in Table 14.

Table 14: Summary of main positive and negative aspects of each function

Function	Positive aspects	Negative aspects
F1: Experimentation by entrepreneurs	- 3 decades of farmer experimentation - Experimentation and demonstration plots across the country	- Infrastructural difficulties - Insufficient market development by market actors
F2: Knowledge development	Formalization of knowledge development through farmer organizations and public higher education system	- Dependency on donor funding - Government functionaries lack knowledge of agroecology - Insufficient human and organizational adaptive capacity
F3: Knowledge exchange	- Farmer to farmer schools and networks - Bachelor, Masters, PhD programs in universities - National networks and roundtables of organizations supporting agroecology - Regional and international knowledge exchange through NGOs and research organizations - Focus on youth outreach - Nascent: training for government employees and awareness-building of consumers	- Dependency on donor funding - "Islands of agroecology" that do not connect to other agroecological projects or organizations - Difficulties of working with municipal governments
F4: Guidance of the search	- Government has written agroecology and related issues into law	- Government does not focus on implementing its policies - Government's two-prong approach (on conventional agribusiness and on agroecology) is confusing for stakeholders - Difficulties of defining "agroecology"
F5: Market formation	Creation of farmer's markets in municipalities and in the capital	- Low consumer purchasing power - Insufficient production of and access to agroecological inputs
F6: Resource mobilization	International financial resource donors	- Lacking financial, human, and physical resource mobilization - Rapid change of government staff makes working with municipal governments difficult
F7: Creation of legitimacy	- Groundswell: 3 decades of farmer-to-farmer movement - Organizations linking farmer organizations and policy-making	- Difficulties of defining "agroecology" - Mixed messages of government - Insufficient creation of market opportunities and infrastructures

F1: Experimentation by entrepreneurs

Representatives of local CSOs and producer organizations who have a broad overview of the types of actors in agroecology defined two different kinds of agroecological entrepreneurs: those related to production (farmers) and those related to distribution (market-related entrepreneurs). Several CSOs, NGOs, and farmer organizations have supported farmer experimentation for the last few decades, and experimentation and demonstration plots have been established across the country. However, participants indicated several issues stifling farmers' experimentation. In workshops, farmers explained that many farmers they know do not perceive agroecological production as a profitable economic activity. This is related to the lack of marketing opportunities and the perceived lack of agroecological products' added value. Rather, agroecology is seen as connected to topics of food security and the scarcity of farm inputs (interviews; Fundación Luciérnaga and SIMAS (2010)). Further, even among some farmers and extensionists who use agroecological practices, the adoption of agroecological systems thinking – i.e. managing the farm as one interrelated system – is more difficult (interviews; Bacon et al. (2014)). Related to this, farmers mentioned that the focus of some cooperatives on the propagation of one crop stifles experimentation: Farmers are supported in producing one crop, which the cooperative then markets collectively, but not in diversifying their cropping systems (which is widely considered to be a basic tenet of agroecology, see e.g. Wezel et al. (2014)). When representatives of cooperatives were asked about this, they explained that the one-crop focus is a practicality issue related to inadequate infrastructure – including good roads – for connecting rural villages to local markets.

Interviewees from CSOs and research organizations in Managua characterized experimentation with national markets and value chain creation by agroecological entrepreneurs as weak but improving (see also sub-section market development below). This experimentation has been led and reinforced by mainly local producer organizations, CSOs, and NGOs, acting with the permission of GRUN institutions, like the Ministry of Family, Community, and Cooperative Agriculture (MEFFCA) or the National System of Production, Consumption and Commercialization (SNPCC). Together with municipal governments, these institutions have worked on establishing alternative food networks in municipalities nationwide, including farmers markets and direct producer-to-consumer networks. A brand for agroecological products has been developed by the Group for the Promotion of Ecological Agriculture (GPAE), with products found in markets and stores in the larger cities and municipalities. However, these marketing opportunities remain isolated and without a "big picture" for national agroecological market development.

Alternative possibilities for farmers' experimentation were given by one interviewee, from an organization focused on finding opportunities for the development of alternative value chain and marketing arrangements between rural production and urban consumption zones. One suggestion was the development of ecotourism on agroecological farms. Such agri-ecotourism opportunities are currently found mainly in the coffee zone (around Matagalpa) and on permaculture farms on Ometepe Island.

F2: Knowledge development

In workshops, farmers identified knowledge development as a function strongly filled by the AeIS. As mentioned above, three decades of agroecological knowledge-building and sharing by and between farmers has been a key point in creating a groundswell of knowledge of and support for agroecology. Farmer field schools and experimentation plots exist across the country. Workshop participants and interviewees from organizations in Estelí found these to be central in furthering specific local knowledge development of farmers about agroecological production. They also serve in peer-to-peer knowledge exchange by farmers (see section on knowledge exchange below). Agroecological knowledge development has been formalized in national higher education curricula: The National Autonomous University in Léon (UNAN-Léon) has the oldest agroecological university program in the country, and the National Agrarian University (UNA) in Managua offers multiple degrees from technical to masters' level and a doctoral program in agroecology. Particularly in formally institutionalized agroecological knowledge development though higher education institutes, Nicaragua has the potential to be a regional "lighthouse" (Salazar-Centeno 2013).

Since 2007, the government's National Agricultural Technology Institute (INTA) has been given the lead role in linking research and policy (Fréguin-Gresh 2017a). For example, INTA institutionalized a system of community seed banks (CSBs), spearheaded by PCAC-UNAG since 2002; by 2015, 380 CSBs existed nationally (McCune 2016). In 2016 and 2017, INTA organized the First and Second International Congress on Agroecology in Managua – represented parties were national and international researchers, farmers, CSOs, government initiatives, and small companies offering agroecological inputs and products.

However, literature and policy documents show, and interviewees from NGOs and national universities confirmed, that much of the agroecological research and development sphere remains very dependent on international donor funding (Fréguin-Gresh 2017a). For example, an interviewee described a study financed by an Austrian development organization that discovered a producer who controlled rat populations using a native tree that naturally repels rats. This old cultural knowledge had been hitherto unknown to scientists and came to the forefront through this donor-funded study. Two interviewees decried that in some instances donors have taken control of the organization or project – e.g. SwissAid of the national "Alliance for Seed Identity" (ASI), a network of organizations fighting for national seed sovereignty.

Most authors agree that agroecology is highly knowledge-intensive (Altieri and Toledo 2011; Holt-Giménez and Altieri 2013; Caron, Biénabe, and Hainzelin 2014; Bellamy and Ioris 2017; Isgren and Ness 2017; Miles, DeLonge, and Carlisle 2017). This indicates that not just farmers and technicians need practical knowledge, they also need social and economic knowledge, as one interviewee pointed out. Further, to be able to fully realize an agroecological transition, institutions and government functionaries need new organizational and technical knowledge, and the adaptive capacity to internalize

and apply it. Agroecological knowledge development in Nicaragua has been hindered by a lack of human and organizational adaptive capacity: on the World Bank's statistical capacity index (which approximates a country's ability to collect, analyze, and disseminate high-quality data about its economy and population), Nicaragua's score has recently decreased to 70 after a 2005 high at 83 (World Bank 2017). An important step to grow government functionaries' knowledge has been made by UNA, whose agroecology degree programs have been frequented by employees of INTA.

F3: Knowledge exchange

Interviews and literature showed that the formal knowledge exchange infrastructures include farmer-to-farmer schools and networks and the national research institutes and international networks mentioned above. The technical and bachelor-level curricula of the national public higher education system includes agroecological knowledge via environmental knowledge and social justice classes (interviews; MAGFOR (2013)). The Rural Workers' Association (ATC) has established several agroecology schools around the country based on the model of international peasant organization La Via Campesina's schools and the Freirian model of public education (McCune et al. 2016). Interviews with NGOs and research organizations and organizational documents showed that in recent years, organizations as varied as the PCAC-UNAG, ATC, and MAONIC, the coffee cooperative PRODECOOP, and NGOs such as the Tropical Agricultural Research and Higher Education Center (CATIE) and the Mesoamerican Information Service on Sustainable Agriculture (SIMAS) have focused on the systematization of existing knowledge and experiences of farmers, which is crucial to facilitate the exchange of information about successful adoption experiences in communities nationwide (MAONIC 2011; Villanueva, Sepúlveda, and Ibrahim 2011; SIMAS and PCAC-UNAG 2015). Interviewees, particularly of the organizations in Estelí, identified another focus of many organizations working in rural areas: institutionalizing youth outreach and training.

International farmer-to-farmer ties are fostered through producer organizations, NGOs, and CSOs: for example, a 2018 meeting on "Agroecology in Mesoamerica," organized by the intraregional Agroecological Movement of Latin America and the Caribbean (MAELA), GPAE, and ASI, brought together 40 Nicaraguan farmers and 25 producers from several central American and Caribbean countries. Short courses on agroecology, bringing together students and practitioners from the United States and Latin America, have been organized by, for example, the USA-based Community Agroecology Network (CAN) in coordination with the Association for the Development of Nicaragua (ASDENIC) in Estelí. Intraregional institutes, like the Interamerican Institute for Agricultural Cooperation (IICA) and the Latin American Scientific Society for the Study of Agroecology (SOCLA), and national institutes like the Mesoamerican Agricultural Information Service (SIMAS) disseminate agroecological knowledge gathered across Latin America (IICA, MAGFOR, and Cooperación Austriaca 2009; Fundación Luciérnaga and SIMAS 2010; SIMAS 2011b; 2011a).

Looking at organizational networks, in 2007 the now-defunct Organic Roundtable (Mesa Orgánica) for the first time brought together government entities, CSOs, producer groups, and private-sector actors. Interviewees stressed the important role played by the Mesa Orgánica in creating Law 765. In 2009 organic and agroecological producer organizations formed the National Movement of Agroecology and Organic Producers (MAONIC), a national round table with the explicit goal of anchoring organic and agroecological production in Nicaragua's legal framework. Multiple interviewees highlighted MAONIC as currently playing the leadership role in Nicaragua's agroecological movement. The GPAE currently links 36 organizations – farmer cooperatives, CSOs, local farmer-to-farmer groups affiliated with UNAG (PCAC-UNAG) groups, and research institutions. Its programmatic goals include putting pressure on the GRUN to fulfill its commitments to agroecological development as specified in Law 765 (GPAE 2013). Looking at international knowledge exchange, civil society and research organizations have come together in the Alliance for Agroecology, a network of institutions in seven Latin American countries that investigates not just agroecological practices, methodologies, and benefits, but also the processes through which CSOs and governments have formulated public policy promoting agroecology. SOCLA has in recent years opened a chapter in Nicaragua, based at the UNA in Managua, and was instrumental in supporting the UNA in conceiving and implementing its PhD program in agroecology. MAELA, formed in 2009, ties together organizations from agroecological movements across the continent. Interestingly, interviewees confirm that ties to international peasant organization La Via Campesina (LVC), a major player in agroecology in countries around the world, are almost completely lacking. Currently, the ATC is the one of the few Nicaraguan organizations that remains a member of LVC, but not even the PCAC-UNAG is still a member.

Realizing that government functionaries lacked information on agroecological farming, in 2016 the GRUN (led by INTA) implemented technical capacity-building in agroecological principles and practices for 72 functionaries in the SNPCC. Other government functionaries have attended UNA's agroecology programs. Knowledge exchange has traditionally been weak on the demand side – Nicaraguan consumers are largely not aware of the benefits, be they social, ecological, or health-based, of consuming nationally and sustainably-produced food (interviews; Fundación Luciérnaga and SIMAS (2010). Organizations such as GPAE and several local CSOs are now working to increasing consumers' awareness of these benefits (particularly in the larger cities and municipalities around the country) through advertising and public awareness campaigns on TV and in national print media (Gutiérrez 2017).

Finally, although it appears that several networks supporting the agroecological transition exist in Nicaragua, multiple interviewees commented on the "islands of agroecology" within Nicaragua's AeIS. They explained that although many groups support agroecology, their work is undertaken without a bigger picture approach and in isolation, without an overarching vision or alignment with other stakeholders' foci; hence, they fail to capitalize on existing synergies. Another example of this given by interviewees in this study is the ATC, which, as several interviewees from organizations working at the

national level explained, works independently from other national organizations. A further example, expressed by interviewees from organizations in Estelí, is difficulties in working with municipal governments because they are mostly funded by, and answer directly to, the national government, municipal governments must get approval from the national level before participating in local projects. This process is usually arduous and time-consuming, and often results in non-approval from the national government. Hence, municipal governments' action radii are limited; this means most rural projects function independently although they may be located in the same zone.

F4: Guidance of the search

Literature and policy documents show that Nicaragua's government has been the principal provider of credit, technical assistance, and social services to the agricultural sector since the 1980s (Saravia-Matus and Saravia-Matus 2009; Araújo and Godek 2014; Fréguin-Gresh 2017a). In recent years, the GRUN has instituted a two-pronged plan for agricultural development: supporting big agribusiness growth, on one hand, and smallholder production on the other (Ripoll 2018).

In 2011, the GRUN passed Law 765, the Agroecology and Organic Production Law (GRUN 2011), followed in 2013 by the associated Technical Norms for Agroecological Production (NTON 11-037), which provide standards for agroecological production units (GRUN 2012). Law 765 is part of a host of legislation concerning broader social and environmental justice issues that has been passed by the GRUN since 2007 (see Table 15) (MAGFOR 2013). Like other laws on related issues like food sovereignty, it was formulated through a process of stakeholder consultation (Godek 2015). Yet, it became clear during the consultations that different organizations were promoting different definitions of (agro)ecological agriculture (Alianza por la Agroecología 2014b). Further, interviewees from NGOs and producer organizations in the capital maintained that outside influence in the formulation of Law 765 – specifically, the FAO's involvement (as requested by a government functionary) – watered down the law by, for example, deleting the term "food sovereignty" and leaving in "food security." As interviewees stated, the competing discourses – of organic and agroecological production – can be seen in the wording of the law (this is also highlighted by Alianza por la Agroecología (2014b)). Interviewees from agroecological organizations, in particular, feel that the law focuses more on the model of organic farming: it combines agroecological and organic production into one piece of legislation, and the NTON 11-037 are unrealistically precise (mirrored in statements in Alianza por la Agroecología (2014b)).

Table 15: Legislation on agroecology and related topics since 2007

Year	Law (number, issue)
2007	620: Regulation of national water sources
2008	648: Equal rights and opportunities for all citizens

Year	Law (number, issue)
2009	693: Food and nutrition security and sovereignty
2010	705: Regulating the use of biotechnology
2011	747: Animal rights
2011	765: Agroecological and organic production
2012	807: Conservation of biodiversity

In interviews, stakeholders, including farmers, technicians, and researchers, perceived the Nicaraguan government as providing inconsistent guidelines for agricultural development. Actors see this as an effect of the government's business-as-usual attitude towards conventional agricultural production, including the continued subvention of chemical inputs and persistent favoritism in government policies towards large landowners with intensive mono-cropping, animal production, or highly agri-chemical input dependent crops such as tobacco (Alianza por la Agroecología 2014b). Issues mentioned in the workshops that affect would-be agroecological farmers included the insecurity of land tenure and plot fragmentation; the inherent insecurity of being a small, nature-dependent producer; and the secure income offered if farmers lease their land and labor to tobacco farms. Farmers feel that these issues are not addressed by the national government. Further, interviewees indicated that crucial issues stipulated in Law 765, including specific financial instruments for agroecological farmers and the creation of a national council to support agroecology, have not been implemented (reflected also in Alianza por la Agroecología (2014b)). Working with municipal governments was highlighted as difficult by interviewees, as the former do not have a specific office for agroecology and contact must be made through one of the municipal commissions on related subjects such as food security or environmental protection (Sánchez Gutiérrez, Vásquez Zeledón, and Ripoll (2017) mention this too). Hence, as other authors have noted, regarding, for example, the implementation of food sovereignty in agri-food policy, "while the law provides a clear institutional structure, it lacks a 'road map' for the implementation process" (Araújo and Godek 2014, 69). Further compounding the confusion are the GRUN's conflicting demands and policies. For example, the GRU calls for rapid crop yield increases and simultaneously for agro-ecosystem restoration, a medium- to- long-term process. The GRUN's policies support agroecology but also continue to regard the export-oriented production of high-value crops as a pillar of national economic development (Fréguin-Gresh 2017a). This latter focus includes, for example, continued state subventions for fertilizers such as urea (Baca Castellón 2018). Since 2013, the government has been flirting with a "middle path" of agroecology that allows the use of certain agri-chemicals (defined as "green" in the government's "stoplight" – i.e. green/yellow/red list of harmful agrichemicals) in agroecological farming (Baca Castellón 2015), even though this is forbidden by Law 765.

Mixed messages stem from not just the government itself, but also from closely affiliated organizations such as UNAG, the nation's largest association of small- and medium-sized producers. Although it was instrumental in introducing agroecology in Nicaragua, UNAG has swung back and forth on including agroecology in its programs. Because it re-involved itself in agroecology so late, interviewees from other organizations fear that UNAG's associates lack appropriate knowledge of current agroecological practices and paradigms. From farmers' perspectives, organizations promoting both conventional agriculture and agroecology are very confusing. A specific example given was farm visits from both conventional and agroecological extension agents from ASDENIC, which operates in northern Nicaragua. Farmers and CSO representatives lamented that this inhibits farmers' experimentation with agroecological practices and undermines agroecology's legitimacy.

F5: Market formation

Dividing market formation into input- and output-related markets highlights disparities in market development. Input markets for agroecological inputs (e.g. clean native seeds, bio-fertilizers, and organic pest and disease management products) have been slow to develop, with farmers in workshops and interviewees from universities and NGOs highlighting sufficient seed production as particularly problematic. In workshops, farmers described the lack of timely access to clean native seeds and pest and disease management products as a main hindrance to adopting agroecology. Other interviewees from local organizations in Estelí mentioned the lack of sufficient manure to fertilize fields as a large hindrance affecting particularly the most resource-poor farmers, who may not own the large livestock that produces manure.

Output markets have mushroomed in recent years. The GRUN, municipal governments, and CSOs have supported the opening of farmers' markets in municipalities nationwide. Stores selling agroecological products have opened in municipalities and cities across the country. Several farmers' markets in Managua and surrounding towns foment direct interaction between consumers and producers. Farmers selling here do not necessarily have to be certified but must be using ecological practices, without agri-chemical use, on their farms (La Prensa 2015). Urban consumers can participate in community-supported agriculture schemes, or shop in grocery stores devoted to local and ecological products. Agroecological products are being marketed towards the tourist segment: producer groups market directly to stores and restaurants in tourist hot-spots such as Granada, San Juan del Sur, Léon, and Rivas (El Nuevo Diario 2017). GPAE has developed a collective brand for agroecological products, focused on the national market. Other certifications exist through BioLatina, which works through collective certification, mostly for organic products destined for export. Further market-related changes include the first national trade fair, organized in 2017 by INTA and MAONIC, for small and medium-sized agroecological and organic producers. This event brought together producers and organizations from around the country with consumers in Managua.

Yet, other problems persist. Visits to farmers' markets in the municipalities have shown that often, agroecological products sold there are not differentiated from conventional products; hence, there is no price premium. In Managua, some farmers sell agroecological produce in farmers' markets, but this is based on individual trust between producer and consumer. Further, these markets tend to be small in terms of consumers. Although urban demand is growing, the financial constraints of many urban consumers limit the size of this market; this issue is more pronounced in rural areas. To overcome these issues, interviewees noted that several organizations are working together to create four large central markets in Managua where producers can directly interact with urban consumers. Certifications, such as offered by BioLatina, may be prohibitively expensive for cooperatives. A (low-cost) public certification scheme for agroecological and organic products has been developed based on Law 765 and the NTON 11-037, but has not been implemented (Alianza por la Agroecología 2014b). A different issue raised in interviews was skepticism concerning consumers' willingness to pay a price premium for agroecological produce, which was perceived as linked to consumers' lacking information on the benefits of purchasing and consuming locally and agroecologically produced food. Finally, three interviewees explained that insufficient production of large quantities of agroecological products is a bottleneck These interviewees explained that national market opportunities involving the production of large quantities of agroecological produce, such as selling to the national supermarket chains, involve too many intermediaries and long value chains (from the producers' perspective) and too low, or unstable, volumes of production of too many products (from the supermarket perspective) (as also noted by Michelson, Reardon, and Perez (2012)). As one interviewee mentioned, several years ago the now-Vice President of Nicaragua, Rosarillo Murillo, attempted to launch a program to procure all foodstuffs for government canteens from national agroecological farms. Yet, the relatively small quantities produced by agroecological farmers, and the lack of an organization to coordinate this nationwide, meant that this demand could not be satisfied by production levels.

F6: Resource mobilization

In the workshops and interviews, all participants perceived resource mobilization as lacking in financial, physical, or human aspects. Financial infrastructure is missing in two main areas: 1) support for farmers during the time of transition to agroecology and 2) in specific financial products for agroecological farmers. While transitioning to agroecology, yields are often low; farmers and technicians mentioned the time lag between investment and higher productivity as a large deterrent to farmers' adoption of agroecological practices. Interviews indicated that although agroecological farmers face different risks than conventional farmers, no specific financial instruments for agroecological production, like credit or insurance, are available from national banking institutes – not even from the Banco Produzcamos, the GRUN-mandated bank for small and medium-sized farmers, specifically mentioned in Law 765 as the go-to bank for agroecological producers (Alianza por la Agroecología 2014b). Particularly the lack of a specific GRUN budget dedicated to the development and implementation of agroecology programs,

including research on bottlenecks like insufficient production of and access to bio-inputs, has hampered further implementation of Law 765 (Fréguin-Gresh 2017a; Baca Castellón 2018). This means that the mobilization of financial resources for agroecology has been strongly led by international donor organizations, and not by the national government (Fréguin-Gresh 2017a). Many (national) NGOs with international financing have projects on agroecological themes. One interviewee sees this as a result of the drawback of the state during the neoliberal regime of the 1990s, during which NGOS mushroomed into the spaces vacated by the public sector. A related concern, mentioned by interviewees from organizations that work with the government, is the issue of globalization, which has opened opportunities for transnational companies' investment in Nicaragua – but this investment usually does not consider social or environmental dimensions. Nicaragua has a friendly climate towards foreign direct investment. In 2017, PRONicaragua, the government agency in charge of foreign investment, was recognized by the World Bank as one of the world's top investment facilitators, a recognition given for the first time given to an institution in a developing country (Ripoll 2018). According to interviews, an unexplored issue is the question of ecosystem services payments for agroecological farmers. Interviewees from NGOs and research organizations expressed that this could take two forms: a direct valorization of, and payment for, ecosystem services provided by ecological agriculture, similar to what exists in other countries, or a more structural change, by integrating the costs of negative environmental impacts caused by conventional agriculture into a national cost-benefit scheme.

Concerning physical resources, technicians and farmers mentioned lacking sufficient and timely access to bio-inputs (clean native seeds, organic fertilizer, biological pest- and disease-control products) as a large hindrance to farmers (see sub-section on market formation above). In workshops, farmers talked about the fragmentation of their fields into disparate plots, making it more difficult to implement time- and labor-intensive agroecological practices, as economies of scale are not possible. Fragmentation of fields also makes more pertinent the problems caused by neighboring conventional farmers' fields' agrichemical runoff, which negatively impacts efforts to maintain agroecological fields as well as certification standards.

Farmers indicated that insufficient availability of manpower in rural areas hinders the spread of labor-intensive agroecological production. Many small farmers, particularly in the tobacco and sugarcane growing areas, find it more financially stable to rent out their land to these agro-industries and work as laborers therein. As is the case in many countries, many rural Nicaraguan youth see more opportunities in urban areas and overseas. These factors lead to a lack of manpower for agricultural production in rural areas. Human capacity in government institutions was seen as severely lacking by interviewees. In particular, MEFFCA, which is responsible for agroecological market development, was perceived as lacking sufficient human resources to support all the projects they are supposed to be running. Municipal governments, which could be implementing agroecological projects, must work solely with government institutions and funds, and thus lose out on the knowledge and capacity of local producer organizations, NGOs, and CSOs. A separate issue mentioned in interviews was the rapid change of government

officials, particularly at the municipal level, which was seen to impede the creation of stable relationships and hence, hinder the institutional anchoring of and government support for agroecological projects in the municipalities.

F7: Creation of legitimacy

The interplay between "top-down" (government policy and strategies) and "bottom-up" (through the farmer-to-farmer outreach of producer organizations and CSOs) actions for the agroecological transition has shaped the development of the AeIS since the 1980s by creating legitimacy for agroecology at both national policy and grassroots levels. Organizations that work on both aspects, such as MAONIC, have played an important role in presenting agroecology as a productive alternative - increasing environmental sustainability and food security of farming systems - to both local organizations and national policy-makers. Particularly MAONIC plays a central role in strengthening agroecology's legitimacy, with interviewees from organizations in the capital and in Estelí mentioning the organization as holding a leadership role in furthering the agroecological transition in Nicaragua. Other actions that support the creation of legitimacy for agroecology include territorial-based initiatives, such as those pushed by the Association for Rural Agroecological Development (ADAR) since the 1990s, and which have been undertaken by multiple institutions. Agroecology's growing legitimacy within the formal research and education communities can be seen in UNA's development of a doctoral program in agroecology and INTA's organization of the Agroecology Congresses in 2016 and 2017. These factors have increased agroecology's legitimacy nationwide, but interviewees identified (and documents bolstered) three issues that significantly lessen agroecology's legitimacy: 1) different definitions of ecological agriculture held by organizations, networks, and the GRUN; 2) mixed messages concerning agroecology (discussed above in the sub-section on guidance of the search), evidenced perhaps most clearly in the legislation but non-implementation of Law 765; and 3) insufficient creation of market opportunities and financial infrastructures (see sub-section on market creation above). The lack of agroecology's legitimacy at a national level may perhaps be exemplified in the fact that agroecological farmers are not counted by Nicaragua's agricultural census, held every decade, and interviewees do not think that agroecology will be included in the next census either.

Table 16: Systemic problems hampering the further growth of the agroecological innovation system in Nicaragua

System function	Systemic problems hampering system functions	Description of links between systemic problems
F1: Experimentation by entrepreneurs	Missing actors Interaction failure Hard institutional failure	Different groups of actors are affected by different systemic problems. Experimentation by the private sector is weak esp. concerning market development, as they don't see opportunities for financial gain – this is related also to lacking information/demand on consumer side. Amongst farmers, experimentation is stifled by the 1-crop-focus of some cooperatives, as well as by opposing policies within and between government institutions. Further issues include land tenure insecurity, land fragmentation, and the lack of government (financial) support for farmers in transition period.
F2: Knowledge development	Missing actors, Hard institutional failure Lacking capacity of actors	This relates to weak human, organizational, and institutional adaptive capacity, connected to the lacking guidance of the search at national level. Related to this is weak consumer knowledge and market development – most ecological production focuses on export crops, and the national market is incipient.
F3: Knowledge exchange	Hard and soft institutional failures Infrastructure failure Interaction failure	Connected to the "islands of agroecology", weak organizational capacity, and weak guidance of the search, knowledge exchange between different stakeholder groups remains weak.
F4: Guidance of the search	Missing actors, hard institutional failure Interaction failure	Lacking coherence of government policies concerning agroecological and conventional agriculture lead to further mismatch between national policies and their implementation at municipal scales.
F5: Market formation	Lacking presence and quality of actors and infrastructures Hard and soft institutional failure Interaction failure	National input and output markets growing but insufficient, including the lack of consumer awareness of benefits of buying agroecological products, lacking differentiation of agroecological products in markets and connected to this, the lack of a price premium. Lacking knowledge of NTON 11-037 and certification possibilities, by farmers and technicians, further impedes market development.
F6: Resource mobilization	Lacking presence and quality of actors, interactions, institutions, infrastructures	Lacking resources include financial instruments for the parameters of agroecological production, lacking sufficient and timey access to bio-inputs, and low profit margins for producers.

System function	Systemic problems hampering system functions	Description of links between systemic problems
F7: Creation of legitimacy	Lacking presence and quality of physical and financial infrastructures; hard and soft institutional failure	Countermanded through government's continued focus on conventional production, as well as by contradictory policies within and between government institutions, including lacking resource mobilization and market development.

4.4.4 Interdependence of systemic problems

The functional-structural analysis in Table 16 above presents systemic problems that deter the development of the agroecological innovation system. The results show how weaknesses of the structures, and ensuing interactions between them, form the blocking mechanisms hindering the further diffusion of agroecology. Three central conditions cause a chain of issues that negatively impact the further diffusion of agroecology, with the feedback between them causing vicious cycles of problems (Hekkert et al. 2007): 1) The lack of a shared common vision for development of the agroecological innovation system negatively impacts every other aspect of the system; 2) hard and soft institutional problems hamper experimentation by entrepreneurs and market formation; and 3) the lacking creation of legitimacy causes vicious cycles throughout the system. These blocking mechanisms are illustrated in the following sub-sections.

4.4.4.1 A lacking common vision for agroecology negatively impacts all other functions in the system

Lack of a common vision for agroecology resonates and creates problems throughout the system (see Figure 21) and is partially caused and affected by the lacking guidance of the search by the government. This in turn feeds into, and is fed by, incoherence in government policies. Policy mismatches may be found within institutions, between institutions, and between levels of government (i.e. national and municipal). All these issues mean that stakeholders, particularly those government-affiliated, are not coordinating their actions to the extent they might to leverage scarce resources. This, in turn, feeds into vicious cycle 2: the non-mobilization of government and national funds in turn implies that international donor funding remains an important source of financing for agroecological projects. Since donor funds tends to be localized in distinct projects, not contributing to an overarching plan of national agroecological development, the creation of legitimacy for agroecology is further negatively impacted. Further, without the security of national legitimization of agroecology, experimentation by both farmer-entrepreneurs and market entrepreneurs is weakened. The lack of financing for agroecology feeds into vicious cycle 3: the absence of market formation results in reciprocal negative effects concerning experimentation by entrepreneurs. The lack of financing also means that little consumer-side knowledge

development is initiated, further weakening consumer demand and the creation of markets. This connects to vicious cycle 4: the incoherence of government policies, particularly between national and municipal legislation and implementation, negatively impacts not just financial, but also human resource mobilization. This in turn limits market formation and entrepreneurial experimentation.

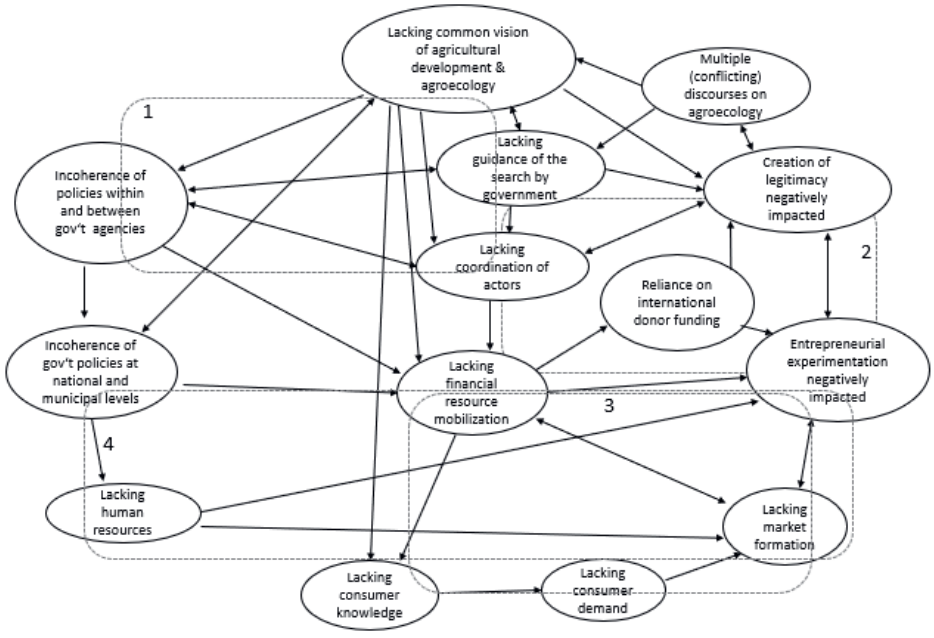

Figure 21: The lack of a common vision for agroecology as a central blocking mechanism impacting all other system aspects (vicious cycles 1 - 4 identified by dotted lines; arrows indicate one-way or two-way relationships between issues)

4.4.4.2 Hard and soft institutional problems negatively impacting experimentation by entrepreneurs and market formation

Experimentation by both market entrepreneurs and farmer entrepreneurs is negatively impacted by hard and soft institutional problems that reverberate throughout the system (Figure 22 and Figure 23, respectively). Government policies and strategies have emphasized agroecology, particularly as part of the national (food) sovereignty rhetoric, but their implementation has focused on the technical and knowledge aspects of production without linking to the necessary demand-side institutional innovations (Figure 22). Particularly weak are the creation of the relevant physical and financial infrastructures for (input and output!) market development, links with private sector actors, and the fomenting of consumer demand. A vicious cycle can be seen in the links between weak market development, weak knowledge development by market entrepreneurs, their lack of experimentation, and insufficient creation of legitimacy for agroecology.

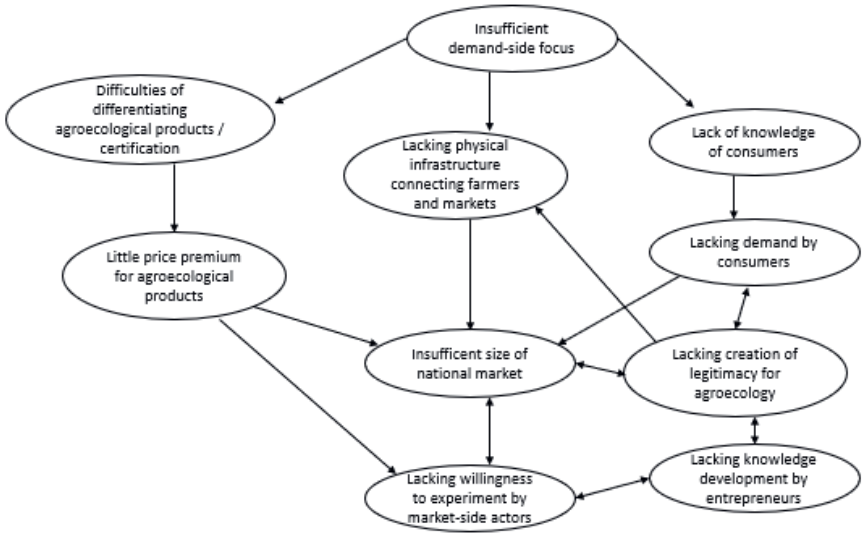

Figure 22: Hard and soft institutional problems weakening market entrepreneurs' willingness to experiment (arrows indicate one-way or two-way relationships between issues)

Farmers' experimentation has historically driven the diffusion of agroecology in Nicaragua. However, we find that hard and soft institutional problems negatively impact farmers' resources and their ability to experiment with agroecological practices on their farms (Figure 23). These hard institutional failures include land tenure insecurity, land fragmentation, and contamination of agroecological fields with agrichemicals from neighboring conventional fields; renting out fields that were being ecologically managed to agro-enterprises that then use conventional methods to grow monocultures; lacking manpower; missing financing mechanisms appropriate to the specific parameters of agroecological production; and lacking infrastructure to get their products to markets, which leads to the necessity of using middlemen who may capture added value. Further, because the government lacks a clear idea of the further development of agroecology and continues to focus on conventional agriculture, the same institutions may provide extension for both conventional and agroecological agriculture, which may be very confusing to farmers.

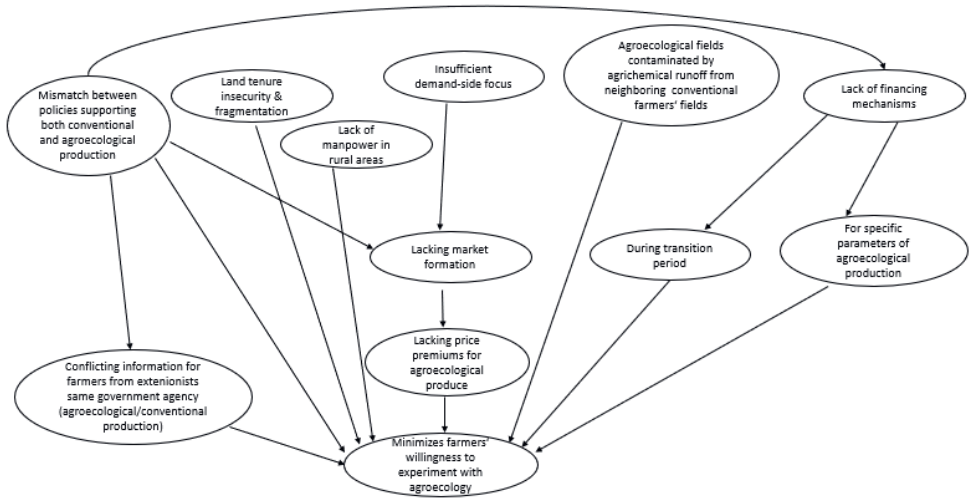

Figure 23: Hard and soft institutional problems negatively impact farmers' willingness to experiment with agroecology (arrows indicate relationships between issues)

4.4.4.3 Lacking creation of legitimacy creates vicious cycles throughout the system

Lacking creation of legitimacy seems to impact negatively on many of the other system functions, creating vicious cycles that reverberate throughout the agroecological innovation system (Figure 24). A central reason for the insufficient legitimization of agroecology are the multiple discourses on agroecology, which run parallel to each other and compete for dominance. On the one hand, the more production-oriented approach is reflected in what we can call the "organic discourse," while the social and environmental justice aspects of agroecology are more broadly reflected in the "agroecological discourse." The conflicting discourses are also found in different organizations that work with farmers, each using their specific definition of agroecology. Further, some organizations that do rural extension have different departments focused on conventional and on agroecological agriculture, with extension agents promoting one or the other – at times to the same farmers. These conflicting discourses feed directly into the contrary policies and practices, supporting either conventional agriculture or agroecology, which are found within government agencies, between different government institutions, and between government institutions operating at national and municipal scales of government. Hence, we see that the institutional framework supporting agroecology is fragmented, with a semi-developed framework for theory and practice of each discourse.

Figure 24: Insufficient creation of legitimacy causes vicious cycles throughout the agroecological innovation system (cycles 1 - 4 identified by dotted lines; arrows indicate one-way or two-way relationships between issues)

Four vicious cycles can be identified. In cycle 1, insufficient creation of legitimacy and the continued conventional agriculture focus of the government influence each other and lead to the weak mobilization of financial resources. This feeds into cycle 2, in which the lack of financial resources and the focus on conventional agriculture lead to insufficient market development and insufficient consumer demand creation, which also impact negatively on each other. Elements of vicious cycle 3 connect to issues in the other three cycles. The insufficient creation of legitimacy for agroecology is intimately interlinked with the multiple conflicting discourses on ecological agriculture, which both feed into and are influenced by the lacking guidance of the search by the government. Lacking guidance of the search is exemplified by the government's continued focus on conventional agriculture and policy mismatches between and within government institutions and levels; these lead to a lack of incentives for entrepreneurial experimentation and activity, as demonstrated in vicious cycle 4.

4.5 Discussion

4.5.1 The role of interconnected problems hindering the breakthrough of agroecology

Using the TIS approach, we were able to categorize distinct problems in the functions and the structural components of the AeIS. This adds to earlier work in agroecological literature (e.g. Mier Y Terán Giménez Cacho et al. (2018)) by identifying not just single issues, but interrelationships between problems that form vicious cycles blocking the development of the agroecological transition. Figure 25 illustrates the overarching functional problems hindering the further diffusion of agroecology. It demonstrates the interdependence of the different parts of the AeIS: a weakness in one can have a cascade of (negative or positive) effects in others, an issue mentioned, but not systematically explored, by other authors (e.g. Isgren (2016)). Highlighting the centrality of co-innovation processes by stakeholders from different areas (Klerkx, van Mierlo, and Leeuwis 2012), the TIS approach also enables a differentiated analysis of stakeholders' possibilities to further grow the AeIS.

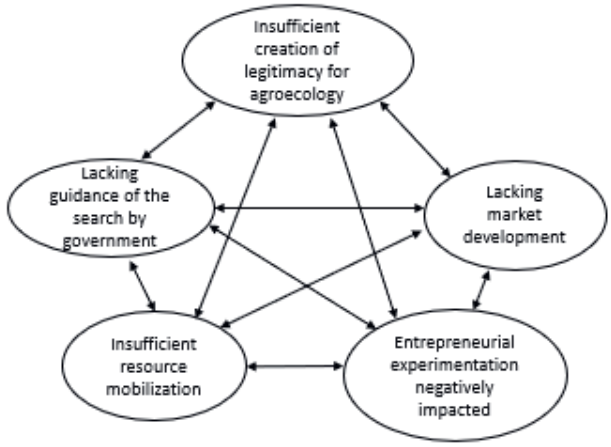

Figure 25: Vicious cycles between central functions that hinder the further diffusion of agroecology (arrows indicate interrelationships between issues)

Figure 25 illustrates that the TIS analysis allows us to identify specific vicious cycles that exist between the lacking creation of legitimacy, guidance of the search, market formation, experimentation by entrepreneurs, and resource mobilization. Interestingly, the functions knowledge development and exchange do not seem to be as affected. Reasons may include the relatively stable institutional setting of the knowledge development and exchange infrastructures, which are based in either the national universities, or in peer-to-peer exchanges by farmers (and technicians). This institutional stability may relate to sunk interests in resources such as knowledge infrastructures (e.g. institutionalized teaching programs from technician to doctorate levels) or physical resources (e.g. land used for experimental

farms, farmer field schools, and demonstration plots). Further, capacity-building is writ large on the agendas of international organizations, which as our research shows, figure prominently in the funding of agroecological projects in Nicaragua.

Authors writing on agroecological transitions have reflected on the difference between "soft" (focusing only on technological aspects) and "hard" (encompassing broader system change, such as changed political and social contexts) agroecological transitions (Angeon and Chave 2014). In Nicaragua, this divide is mirrored in the competing discourses on the more productionist, technologically-focused notion of organic agriculture, and a more comprehensive vision of agroecology, including social justice issues. The struggle between these two discourses strongly negatively impacts the further diffusion of agroecology for several reasons. First, without a clear definition of agroecology, government institutions use one or the other discourse, feeding into conflicting policies within and between state institutions. Second, research institutes, universities, NGOs, and CSOs working in Nicaragua use "their" definition, which hinders their ability to work together and jointly leverage resources. Difficulties that may arise from diverging definitions of agroecology have been highlighted by other authors (Somarriba et al. 2012; Bellamy and Ioris 2017; Giraldo and Rosset 2017; Rivera-Ferre 2018).

Lacking state leadership in promoting agroecology has been regarded a key hindrance to its development, but in Nicaragua, policy is in place. With its enshrinement in national law, agroecology in Nicaragua changed from being a social movement to being formally institutionalized in national policy. This is in line with general trends of agroecology moving into the political sphere (González de Molina 2013; Levidow, Pimbert, and Vanloqueren 2014; Meek 2016; Bellamy and Ioris 2017; Sabourin et al. 2017; Gonzalez, Thomas, and Chang 2018). The policy has enhanced agroecology's legitimacy vis-á-vis conventional agriculture and has boosted institutionalization in knowledge and research institutes and infrastructures. However, our analysis highlights that policy alone is not sufficient to create legitimacy for agroecology. Our study shows disparities between policy and its implementation, a gap which has been identified in literature as blocking general innovation system growth, especially in emerging economies (Intarakumnerd and Chaminade 2007). An understudied aspect of agroecological knowledge development is what forms of knowledge are needed by government functionaries to better support the agroecological transition. The trend of agricultural research and development in emerging economies being dependent on foreign donor funding has been noted by other authors (IFPRI and IICA 2008), as have the mixed impacts of foreign or transnational institutions financing of elements of sustainability transitions in emerging economies (U. E. Hansen and Nygaard 2013; Sixt, Klerkx, and Griffin 2018). Beyond international financing mechanisms, transnational information linkages have also been shown to be important influencers for sustainability transitions in emerging economies (Binz, Truffer, and Coenen 2014). Both trends can be seen in Nicaragua. Historically, Nicaragua was important to the consolidation of LVC as a movement and its framing of food sovereignty (Edelman 2008; Godek 2015; Mier Y Terán Giménez Cacho et al. 2018); currently, multiple networks link national organizations with regional and global agroecological institutions. Hence, Nicaraguan agroecology is

part of the process of "glocalization," in which local practices are informed by (and in turn form part of and inform) an emerging global TIS, a "community that shares cognitive, formal and normative rules" (Schot and Geels 2008, 543). As can be seen by the example of FAO's influence in shaping Law 765, glocalization remains an interesting avenue for future research. Our TIS analysis supports Blesh and Wolf's finding find that agroecological transitions are "socioecologically mediated," i.e. constrained and enabled by biophysical and socioeconomic resources, and multilevel, involving individual as well as collective action (Blesh and Wolf 2014, 433). Further, we agree with Mier y Terán Giménez Cacho et al.'s conclusions regarding the eight drivers of agroecological transitions, which can also be seen as socioecologically mediated (Mier Y Terán Giménez Cacho et al. 2018). As our study demonstrates, a focus on social and environmental benefits, but a lack of attention to the market side, may be detrimental to cementing agroecology's legitimacy, as has been shown for the related subject of food sovereignty (Thiemann 2015). Authors have shown that local market development, favorable to producers, is necessary to further grow the AeIS (Khadse et al. 2017; Mier Y Terán Giménez Cacho et al. 2018). The TIS analysis allowed us to tease apart individual issues. By highlighting their inextricable linkages, it enabled us to untangle some of the thornier issues and supported other authors' arguments for the necessity of coupled innovations between agricultural technologies, institutions, and organizational structures (Khadse et al. 2017; Meynard et al. 2017; Gaitán-Cremaschi et al. 2019).

4.5.2 Contributions to promoting agroecology in Nicaragua

In Nicaragua, bottom-up (lead by grassroots organizations) and top-down (lead by national government) processes are in play, an element which other authors have identified as critical to the diffusion of agroecology (Toledo 2012; Tittonell 2016). Our research has highlighted several other issues that could be improved upon to further the transition. For all of these issues, the creation of a "thick legitimacy" for agroecology – as suggested by Montenegro de Wit and Iles (2016) and including scientific, political, civic, legal, practical, and economic evidence in favor of agroecology – could aid in supporting the agroecological transition.

We agree with Ramos-Mejía et al. (2018) that, in emerging economies, "the role of socio-technological innovation is not only about becoming more resource-efficient, but about reconfiguring power balance within production-consumption systems" (Ramos-Mejía, Franco-Garcia, and Jauregui-Becker 2018, 222). Yet, as also mentioned by Fraser, Fisher, and Arce (2014), this is not (yet) occurring in Nicaragua: conventional agriculture remains entrenched as the main form of production and the question of power imbalances is not addressed (De Laiglesia 2011; Fraser, Fisher, and Arce 2014). This stems partly from lacking policy coordination within and between government agencies, at both national and municipal levels: this negatively impacts all other functions, particularly the creation of legitimacy for agroecology as a viable option for farmers. Yet, the lack of a common vision of agroecology, illustrated by the competing discourses on agroecology, can be identified as a root of the policy mismatches. Without the

development of a solid institutional framework for agroecology, based on a common definition of the term, the further development of agroecology may be difficult. The stronger implementation of the agroecological councils that are written into Law 765 could bring together stakeholders to formulate a joint vision of agroecology and agroecological development in the country. Following Amekawa et al. (2010), the innovative inclusion of non-traditional actors, such as NGOs, CSOs, or private sector actors, in these councils and in agroecological networks could support the development of national market opportunities. The formation of human resources in government organizations – for functionaries implementing agroecology policy, and for researchers and functionaries in the government's Agricultural Research and Innovation System, could aid in bettering policy implementation and research processes (Muñoz Izaguirre 2017).

The problematic of "islands of success" of isolated agroecological projects has been noted by other authors (González de Molina 2013). The development of "agroecological territories," which is already being pushed by multiple research organizations, NGOs, and CSOs, is an important next step in consolidating the "islands of agroecology" working in a specific region (Landero et al. 2016) and enhancing food self-sufficiency (Schipanski et al. 2016). However, in addition to this bottom-up work, processes of territorial consolidation also need supportive public policy, the involvement of local governments, and political will for implementation (OECD, FAO, and UNCDF 2016). Differences within a territory – agroecosystemic and local priorities – need to be considered, as do opportunities to link rural and urban areas, e.g. through more direct interactions between consumers and producers (Vaarst et al. 2017).

Regarding experimentation by farmer-entrepreneurs, a number of barriers stand out: insecure land tenure, which hinders the adoption of agroecological practices (Broegaard 2005; Bandiera 2007; Harvey et al. 2017); severe land fragmentation, which is a severe impediment to the development of integrated farming systems (Dethier and Effenberger 2012; Levain et al. 2015; Isgren 2016); the absence of timely access to sufficient amounts of bio-inputs, including clean native seeds, organic fertilizers, and biological pest- and disease-management products; insufficient availability of rural manpower; insufficient access to credit when needed; and infrastructural difficulties in getting products to markets. These barriers could be addressed by organizations at different levels (e.g. seed propagation by local universities and by individual farmers diversifying into seed production). New arrangements could be made with large-scale ranchers to sell their excess manure to local cooperatives. Universities and INTA could be involved to investigate and produce biological pest- and disease-management products. Land fragmentation and tenure issues are subjects to be addressed by municipal or national government but could be discussed within villages first. Concerning on-farm adoption of agroecology, the impacts of parcel fragmentation have been more studied from a biodiversity perspective (Perfecto, Vandermeer, and Wright 2009; Liere, Jha, and Philpott 2017). Credit issues could be handled by the Banco Produzcamos, which is dependent on national government input or by credit schemes from local cooperatives. The implementation of a public procurement policy, together with the creation of an

organization to bundle production, assume risks, and organize distribution to government centers, could be a tool to grow national markets. Barriers to private-sector involvement in the creation of market opportunities are many, and thus point to focusing on input provision (Henderson and Casey 2015) or on innovative ways of arranging markets for diverse products, such as direct contact between producers and consumers (Lanka, Khadaroo, and Böhm 2017; Vaarst et al. 2017). Beyond the discussion about if it is through overprice or value chains that rentability could be improved, our results suggest that a 'retail transformation' (Reardon et al. 2009), focusing on the health, nutrition, and environmental benefits of agroecological products, could be beneficial to agroecological farmers. As suggested by other authors, the valorization of ecosystem services provided by agroecology could serve as an entry point to increasing agroecology's profitability to farmers (Ponisio and Ehrlich 2016; D'Annolfo et al. 2017; Liere, Jha, and Philpott 2017; Dendoncker et al. 2018). Further, synergies between agroecology and alternative opportunities, such as ecotourism, could be explored.

In Nicaragua, knowledge concerning the technological aspects of agroecology is growing more rapidly than the development of the associated necessary knowledge, physical, and financial infrastructures incentivizing agroecological production and creating consumer demand for agroecological products. As David and Bell (2018) note, instructors should be teaching processes, not just content. In line with Vandermeer and Perfecto (2012), traditional knowledge from farmers and new knowledge generated in universities could be combined to form agroecological knowledge that is both deep and broad. We agree with (Meek and Tarlau 2016b) that critical food systems education, including praxis, policy, and pedagogy, is a path towards reflexive producers and consumers of agroecological products. To grow consumer awareness of and demand for nationally-produced agroecological products, two avenues could be followed. First, following insights from Echegaray (2016), cooperatives and groups like the GPAE could better highlight their corporate social responsibility aspects, related to the ecological and social benefits of promoting agroecological products. Second, an advertising campaign highlighting the benefits of an agroecologically-based agri-food system, emphasizing possible environmental, social, and health benefits, and identifying local points of sale, to air on the government-affiliated television and radio stations that broadcast nationwide. To support phenomenon-based learning processes (Francis et al. 2013), demonstration plots, which can be a driving factor in urban sustainability transitions (Werbeloff, Brown, and Loorbach 2016) and are used widely by farmer organizations in rural Nicaragua, could be placed in urban parks across the country as part of the government's current program of public park rejuvenation. This could bolster agroecology's legitimacy with the Nicaraguan public, particularly if agroecology is framed as an indicator of national sovereignty.

4.6 Conclusion: Understanding and supporting agroecological transitions

Following the central research question – what are the barriers to the agroecological transition in Nicaragua? – we used a structural-functional TIS analysis to identify mechanisms that block the further diffusion of agroecology. We found that using the TIS approach aids in analyzing the growth of agroecology in a holistic manner. Based on results from our case study in Nicaragua, identified some central mechanisms blocking the agroecological transition: policy mismatches, inadequate mobilization of resources, and insufficient market development, which weaken entrepreneurial opportunities and experimentation. Although these blocking mechanisms hindering the diffusion of agroecology are strongly interlinked, the TIS analysis allowed us to pinpoint specific factors empowering these barriers. The results of this research highlight the coupled innovations that are necessary to drive agri-food systems sustainability transitions. A central factor is the fragmented institutional framework concerning agroecology, which inhibits a wide-spread perception of agroecology as a viable alternative to conventional agriculture, as well as hinders concrete actions that could incentivize stakeholders in the agroecological innovation system. Two other, strongly interlinked, factors are the lack of a common definition of agroecology, and the lack of a common vision amongst stakeholders for the development of agroecology vis-à-vis conventional agriculture. These factors open interesting avenues for future research, particularly concerning the power struggles during the development of common definitions of and vision for contested processes such as agri-food system sustainability transitions, the role of politics and the state in transition processes (González de Molina 2013), and the role of individual and organizational agency in transitions. More generally, they indicate that research on transitions towards agroecology would benefit from insights gained from the use of systemic frameworks such as socio-technical systems approaches.

Chapter 5: Nicaragua's agroecological transition: Transformation or reconfiguration of the agri-food regime?

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Abstract

Agroecology started to amplify agroecology in Nicaragua in the 1980s and was translated into national policy in 2011. Using the Multi-Level Perspective on sustainability transitions (MLP), this paper explores whether the rise of agroecology has fundamentally transformed Nicaragua's agri-food system. Drawing on the findings of a qualitative study including a range of agroecological actors and organizations, we create a rich innovation history timeline of Nicaragua's agroecology development at different levels – the agroecological niche (space in which heterogeneous actors nurture innovations) and the regime (dominant agri-food system paradigm). MLP analysis is used to explore the extent to which agroecology's growth has transformed the national agri-food regime. We find that although the term 'agroecology' is used widely by government, incentives for transitions to agroecology are only weakly implemented. This stems partly from the co-optation of the agroecological niche's discourse by regime actors. Currently, it seems the transition process is not a reconfiguration of the agri-food system, but rather that agroecology has been added to the regime without deeper changes.

Keywords: sustainability transitions, Latin America, niche-regime interactions, sustainable agri-food systems, socio-technical transitions

5. 1 Introduction

Agroecology, the ecology of food systems (Francis et al. 2003), has the explicit goal of transforming agri-food systems towards sustainability (Gliessman 2014; La Via Campesina 2015). The debate around agroecological transitions – agri-food systems transitions to agroecology (Duru, Therond, and Fares 2015; McCune et al. 2016; Ingram 2017; Teixeira et al. 2018; Ollivier et al. 2018) – center around how agroecology can contribute to making agri-food systems more environmentally sound and socially equitable (Bellamy and Ioris 2017; Magrini et al. 2019). Such agroecological transitions involve interrelated systemic changes in production and consumption practices, knowledge generation and dissemination, institutional frames, and social and economic relations (Gliessman 2018). Hence, agroecological transitions are multi-faceted, take place at multiple scales (geographic, temporal, institutional, etc.), and involve heterogeneous actors following different aims and innovating in different ways around the central innovation, agroecology (Farla et al. 2012; Meynard et al. 2017; Magrini et al. 2019).

Many authors have documented how agroecological transitions have unfolded, providing rich descriptions of transition players and processes in different contexts (e.g. this journal's issue on "A Brief History of Agroecology in Spain and Latin America" (Gliessman 2017)). Still, systemic and holistic analyses using replicable methods remain scarce (Gaitán-Cremaschi et al. 2019). Contributing to this conversation, this article uses Multi-Level Perspective (MLP) theory, which has been useful for exploring national and regional agroecological transitions (Darnhofer, Sutherland, and Pinto-Correia 2014; Bui et al. 2016) and agroecological transitions in industrializing economies (Gaitán-Cremaschi et al. 2019). Because MLP differentiates between three analytical levels (niche, regime, landscape) whose composition and interactions shape how sustainability transitions unfold, it bases innovations in their contexts and facilitates an exploration of transition dynamics (Geels and Kemp 2007; Ollivier et al. 2018). Seen through an MLP lens, agroecological transitions involve the formation and growth of a new niche – agroecology – within the regime, the national agri-food system. In the agroecological niche, diverse stakeholders co-innovate around the various dimensions of producing, commercializing, and consuming agroecological products (Klerkx, Aarts, and Leeuwis 2010; Ingram 2015; Pigford, Hickey, and Klerkx 2018; Gaitán-Cremaschi et al. 2019). The socio-technical regime is a relatively stable configuration of institutions, regulations, and artefacts that delineate the "rules of the game," defining stakeholders' space and options for movement (Duru, Therond, and Fares 2015). This reflects the dominant industrial agri-food system in most countries (Bui et al. 2016; Gaitán-Cremaschi et al. 2019). The landscape represents the fairly unchanging external conditions outside of the daily reach of regime actors – e.g. international regulations, treaties, and markets, and geo-physical and climatic conditions (Morrissey, Mirosa, and Abbott 2014). It is important to note that niches, regimes, and landscapes are heuristic constructs: in reality, multiple niches may co-exist, and niche and regime actors may overlap (Plumecocq et al. 2018; Gaitán-Cremaschi et al. 2019).

Interactions between the levels drive transition processes (Bui et al. 2016). Yet, in practice, transitions do not always work out and regimes may remain locked into incumbent patterns (Pel 2016). Often, agroecological practices have become marginalized or only very selectively incorporated into incumbent regimes (Isgren and Ness 2017). Using the case of agroecology in Nicaragua, this article examines how the struggle between the niche and the regime shapes the agroecological transition. Nicaragua is particularly apt for this case study, as it is one of a handful of countries with legislation supporting agroecology and the related issue of food and nutritional sovereignty and security. However, despite these progressive policies, the agroecological transition does not seem to be advancing as would be expected. The reasons for this are the object of our present inquiry. The analytical framework used to unpack this question, outlined in section 5.2, adds a discursive element to the standard MLP frame to better capture nuances of niche-regime interactions. Data collection and analysis methods are summarized in section 5.3. Based on an innovation history timeline of niche-regime interactions, section 5.4 discusses the results. Section 5.5 concludes the paper with reflections on the contributions of this case study for unpacking agroecological transitions.

5.2 Analytical framework: Anchoring niche-innovations and regime pushback

Niches and regimes continually interact and influence each other (Raven et al. 2011). Niche-regime interactions take different forms and lead to different transition patterns (Geels et al. 2016; Gaitán-Cremaschi et al. 2019), which may be more radical or more incremental (Ingram 2015; Darnhofer et al. 2016). Far from being monolithic, regimes and niches are semi-coherent, with both alignments and tensions between their components (Ingram 2015). Niche-regime interactions are a two-way street: While niche work to influence the regime, the regime's (re)actions impact the niche's growth and strategies (Ingram 2015; Darnhofer et al. 2016; Pel 2016). On the one hand, regimes seek to maintain the status quo (Plumecocq et al. 2018), meaning they may seek to marginalize or co-opt radical innovations (Ingram 2015). This may be done by "capturing" niches – their apparent acceptance and neutralization by regime actors (Pel 2016). On the other hand, regime actors may induce or assist transitions (Elzen, Van Mierlo, and Leeuwis 2012; Späth, Rohracher, and Von Radecki 2016). These and other tensions within the regime create space for niches to stimulate transformation by 'linking up' and triggering change (Ingram 2015). Figure 26 illustrates a multi-level perspective on anchoring processes within agroecological transitions.

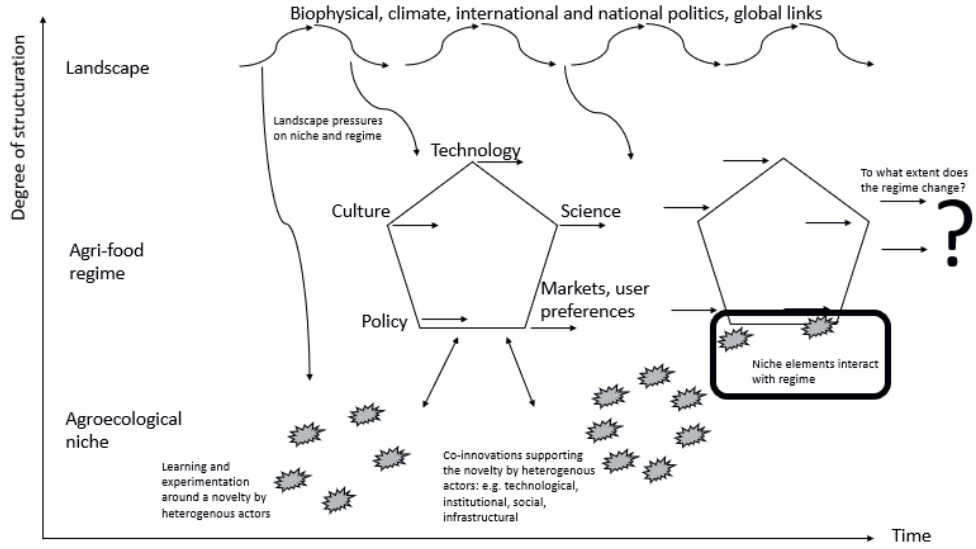

Figure 26: A multi-level perspective on agroecological transitions (adapted from Gaitán-Cremaschi et al. (2019)). The interactions between niche and regime, outlined in the black box, are the focus of this article

Niches link to regimes by anchoring through technologies, networks, and institutions (Elzen, Van Mierlo, and Leeuwis 2012). "Anchoring" refers to the process of embedding niche elements in space(s) created within regimes (Klerkx, Aarts, and Leeuwis 2010; Ingram et al. 2015). In terms of the agroecological niche, technological anchoring refers to the use of agroecological practices and artefacts. Network anchoring refers to the shifting actor coalitions supporting agroecology. Institutional anchoring activities may occur in one of three realms: economic anchoring, by changing rules governing market activities; interpretative anchoring, i.e. of agroecological thought into individuals' sense-making and worldview; and normative anchoring, i.e. of social values and translation of shared goals into public policy (Elzen, Van Mierlo, and Leeuwis 2012). Exploring such linking mechanisms, authors have highlighted the importance of vision-building, the alliance of actors around shared interests, and the creation of shared discourses to embed niche-innovations in regime policies and actions (Bui et al. 2016).

Discourse is fundamentally understood as the interactive processes through which ideas are conveyed (Schmidt 2001). More specifically, discourses are ensembles of multiple understandings and framings produced, reproduced, and transformed to give collective sense to specific issues (Hajer 1995; Geels 2010). Because discourses shape the socio-political legitimacy of niche-innovations (Geels, Hekkert, and Jacobsson 2008), the analysis of discourses utilized by niche and regime actors, and how they change, aids in better capturing nuances of transition processes and power struggles between niche and regime (Geels 2010). This is particularly apt considering the importance of discourse in shaping agri-

food systems' sustainability transitions, and reflects work on defining agri-food systems (e.g. Holt-Giménez and Shattuck (2011). Based on Argumentative Discourse Analysis (ADA; Hajer (1995), we examined story-lines ("how the story is told"), actors ("who tells the story"), and contents ("what the story is about") of niche and regime discourses. Following the anchoring framework described above, we deepen analysis by explicitly considering the dynamics of how discourses have coalesced within the niche and supported anchoring processes.

For the purpose of this study, we define the agri-food system regime at a national level, consisting of the actors, institutions, legal, and organizational frameworks that govern agricultural production and distribution and food consumption. The agroecological niche is defined as the heterogeneous actors, institutions, networks, and infrastructures supporting the growth of agroecology as a set of sustainable and socially-just agricultural practices (cf. Altieri and Nicholls (2017). The anchoring of niche elements into the regime is characterized according to its dimension: technological, network, institutional, and discursive. Regime influences on the niche are broadly delineated. Hence, we capture both niche-regime and regime-niche interactions. Based on the interaction timeline, central elements of Nicaragua's agroecological transition are considered.

5.3 Methods

Results are based on a field study conducted in Nicaragua in two phases (2014 and 2016–2018). Given the broad scale effects of Nicaragua's socio-economic crisis that began in April 2018, the results are valid only for the period leading up to the crisis. Qualitative data collection employed methods including semi-structured key stakeholder interviews, workshops, and the construction of innovation history timelines (Douthwaite et al. 2005) with stakeholders. The study of relevant literature (e.g., scientific and grey) and documents (e.g., government policies and internal documents from relevant organizations) preceded and accompanied the data collection and analysis processes. To capture diverse points of view, stakeholders were targeted at two territorial scales: on farms in and around the municipality of Estelí in northern Nicaragua (targeting farmers and extensionists from local farmer organizations) and in the capital city of Managua (targeting national farmer networks and agricultural research, financial, non-governmental, and government institutions). Snowball sampling was used to identify potential participants in key stakeholder interviews. Stakeholders identified through literature and organizational documents were asked to recommend other participants. Seventeen semi-structured open-ended interviews were conducted in total with representatives from four producer organizations (local in Estelí, national networks in Managua), six national and international research institutes and universities, two government institutions, three national CSOs and one international NGO, and a national financial institute. The interviews solicited information on both respondent's personal experiences with

agroecology and their organization's history of and experiences with agroecology; they were transcribed and analyzed for information as per the elements of the analytical framework.

Farmers around Estelí were invited to participate in workshops based on their membership in local agroecological farmer's organizations that participated in an innovation platform promoting agroecological practices for mixed basic grain production. Three workshops were held in total. One workshop (2014) with technicians from local farmers' and civil society organizations working with agroecology explored views of local agroecological farming systems and how they implement these in projects locally. Two workshops were held with farmers from local agroecological farmer's organizations. The first, held in 2014 with six men and three women, explored perceptions of agroecology and created rich pictures of a) their current farming systems and b) what their farms could look like if more agroecological practices were implemented. The second, held in 2017 with ten men and eight women, was a feedback workshop where farmers discussed their perspectives on the cumulative research results and suggested overlooked issues. The agroecological innovation history timeline was continually refined according to participants' inputs.

5.4 Results and discussion

This section analyzes Nicaragua's agroecological transition to understand how it has been shaped by niche-regime interactions. Although, in Nicaragua, indigenous agroecology was first challenged by agribusiness upon the installation of colonial monoculture plantation structures, many of which remain in place today, this analysis focuses on the period since the 1980s, when efforts to "take agroecology to scale" began (Giraldo and McCune 2019, 8). By 1979, four decades of Somoza family dictatorship and its focus on very large-scale monocropping farming systems (*latifundias*) for export-oriented production had perpetuated poverty and exacerbated extreme social, political, and economic inequalities, with 37% of Nicaragua's rural economically-active population rendered landless (Saravia-Matus and Saravia-Matus 2009) and 70% of the rural population illiterate (Palazzolo 2015). Based on Nicaragua's political history, three distinct periods can be identified since 1979. Following Martí i Puig and Baumeister (2017), we categorize each period in broad political-economic terms: (1) 1979-1990: Nationalist-industrial agri-food system regime, (2) 1990-2006: Neoliberal-industrial agri-food system regime, and (3) 2007-2017: Hybrid developmentalist neoliberal agri-food system regime

We continue by summarizing the political economy of each period and creating a timeline of the central elements anchoring agroecology – (i) technologies, (ii) networks, (iii) institutions, and (iv) discourses – since the agroecological niche began to coalesce (1980s to 2017). We analyze the timeline to understand how the transition has evolved.

5.4.1 Anchoring agroecology: Niche-regime linkages across shifting agri-food regimes

Tensions within the agri-food system regime have created space for agroecological initiatives in different ways. The following section narrates the development of the agroecological niche with anchoring processes italicized in the text. Figure 27 synthesizes central anchoring processes behind the linking up of the agroecological niche to the agri-food system regime

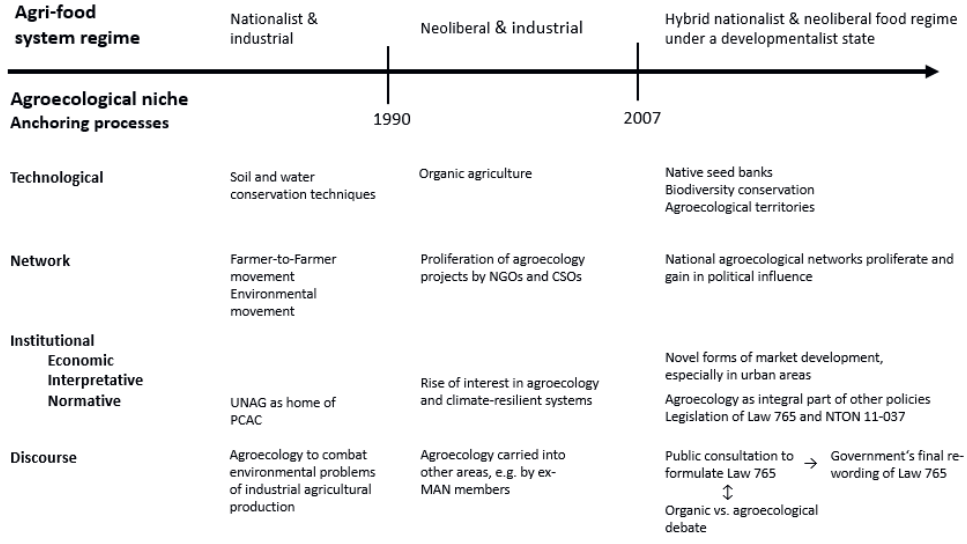

Figure 27: Timeline and categorization of central niche-regime anchoring processes in Nicaragua's agroecological transition

1979 – 1990: Revolutionary government

The agroecological niche in Nicaragua began organizing itself in the early 1980s (Godek 2014; Gonzálvez, Salmerón, and Zamora 2015). After leading the popular revolution that resulted in overthrowing the dictatorship in 1979, Sandinista National Liberation Front (FSLN) leaders governed the country in the revolutionary period, implementing social, political, and economic interventions whilst leading national forces in a proxy Cold War battle, the USA-funded 'Contra War'. The government's goal was food self-sufficiency: agricultural policy sought to industrialize production, centralize domestic trade and imports/exports under state control, and redistribute private landholdings to state-held farms and cooperatives (Castro et al. 2016; Martí í Puig and Baumeister 2017). Sweeping land reforms redistributed 40% of the total agrarian surface area and completely changed land distribution (Núñez Soto 2005). The Contra War and ensuing economic difficulties considerably reduced agri-input imports, instigating a search for local alternatives (Guhuray and Ruiz 1997;

Gonzálvez, Salmerón, and Zamora 2015). Inspired by civil society and non-governmental organizations' work, government institutions and national higher education institutes initiated projects on biological pest control, integrated pest management, biogas production, reforestation, and bio-fertilizer elaboration. In 1987, Mexico's Farmer-to-Farmer Movement (MCAC) was invited to Nicaragua by the National Union of Farmers and Ranchers (UNAG), the then-FSLN-linked mass organization representing small and medium-sized producers' interests (Austin, Fox, and Kruger 1985; Holt-Giménez 2006). Invited to combat widespread soil depletion, MCAC promoters taught soil and water conservation practices to Nicaraguan farmers using horizontal learning techniques (Holt-Giménez 2006) (*technological anchoring*). The Nicaraguan Farmer-to-Farmer Program (PCAC) has since been a pillar of the agroecological niche, supporting the spread of agroecological practices between farmers nationwide, and is organizationally housed within UNAG (*normative institutional anchoring).* PCAC-UNAG was estimated to have reached almost a third of Nicaraguan family farmers by the early 1990s (Holt-Giménez 2006).

The civil-society led Nicaraguan Environmental Movement (MAN) strongly bolstered the early development of the agroecological niche (Godek 2014). Members of MAN began espousing the formation of a government institution for natural resource management in the late 1970s (*discursive anchoring*). MAN was instrumental in laying the groundwork for 1979's creation of Nicaraguan Institute of Natural Resources and the Environment and 1996's General Law on the Environment and Natural Resources (*normative anchoring*). With MAN formally institutionalized only from 1985 to 1995, ex-MAN members spread into many different sectors, seeding agroecological thought in e.g. universities, non-governmental organizations, research institutes, rural development initiatives, and market-oriented initiatives (*discursive anchoring*).

1990 – 2006: Neoliberal era

From 1990 to 2006, three successive conservative governments instituted neoliberal reforms and privatized the agri-food production system. Nicaragua began free market reforms and structural adjustment programs in 1991 (Pisani 2003; HabibMintz 2004), and changes to agricultural policy were made accordingly (García Navarro 2017). Stakeholders related that in the early 1990s, with the rollback of state funding for agriculture, international organizations stepped in, funding projects involving agroecology, but that these projects remained isolated. Organic agriculture grew in importance, with certifications being developed, especially for export-oriented high-value crops like coffee and cocoa (Gonzálvez, Salmerón, and Zamora 2015) (*economic institutional anchoring*). Public awareness of agroecology and its benefits increased after Hurricane Mitch devastated Central American agricultural production in 1997 (*discursive anchoring*): afterwards, agroecological plots were proven as more resilient to devastating climate events (Holt-Giménez 2002; Fréguin-Gresh 2017a; Conz 2018)) (*interpretative institutional anchoring*).

New central actors emerged to promote agroecology. The Mesoamerican Agricultural Information Service (SIMAS), formed in 1992 by ex-MAN members, stimulated the formalization of farmers' and scientific agroecological knowledge (*technological anchoring*). In 1994, the Group for the Promotion of Ecological Agriculture (GPAE), an umbrella organization initially encompassing some 70 organizations from the rural and civil society sectors, was established and began initiating agroecological projects nationwide (*technological anchoring*). In 1996, the Nicaraguan Network for Community Commerce (RENICC) was founded and began supporting the creation of alternative channels of community commerce based on principles of social justice and agroecology (*economic institutional anchoring)*. The anti-GMO movement coalesced in 2002 in the Alliance for a Nicaragua Free of Transgenics (later known as the Alliance for the Protection of Biodiversity) (Godek 2014) (*discursive anchoring*).

2007 – 2017: Hybrid tendencies

With Daniel Ortega's 2006 re-election to the presidency, the FSLN returned to power. Ortega's economic policies have largely continued the neoliberal agro-export model but added broader social policies (Otero 2012; Gonzálvez, Salmerón, and Zamora 2015; Martí í Puig and Baumeister 2017). A cornerstone of Ortega's policies and activities is his politically motivated 2006 pact with the private sector (Thaler 2017). The administration's business friendliness can perhaps best be illustrated by the World Bank's 2017 recognition of Nicaragua as one of the top five global destinations to do business (Ripoll 2018), an explicit governmental goal since 2013 (Spalding 2017, 150). The government's position on agroecological anathemas, such as genetically-modified crops, has been equivocal (Álvarez-Guevara et al. 2012). Although an anti-GMO biosafety law has been passed, it has not been regulated, so it cannot be enforced (SIMAS 2015). Biosafety regulations have been instituted that may open the door for GMOs in the future, even in the face of the anti-GMO law equivocal (Álvarez-Guevara et al. 2012). On the other hand, the government has also implemented policies espousing food and nutritional sovereignty and security and included agroecology in a myriad of governmental initiatives (cf. Godek 2014; 2015). Agroecology initiatives introduced by the government through various state institutions, including landrace seed banks, rural technical education programs, and farmers' markets, have contributed strongly to the geographic spread of agroecology (see FAO 2016; McCune et al. 2016 provide details).

In the past decade, existing agroecological actors have strengthened their ties and expanded the scope and practice of agroecology. This has increased the political struggle between NGOs and the government, as many initiatives have been funded through international sources – what Mier Y Terán Giménez Cacho et al. (2018) call external allies. While external allies can provide key support, particularly financially, their involvement calls into question the medium- and long-term sustainability of transition processes (Rosset and Altieri 2017). Civil society actors have created strong networks such the Seeds of Identity Alliance (linked to the anti-GMO movement) and the now-defunct Organic

Roundtable, from which emerged the National Movement of Agroecological and Organic Producers (MAONIC), arguably the most influential agroecological network. MAONIC represents organic and agroecological farmer organizations from across the country (MAONIC 2011) (all: *network anchoring*). It was key in promoting and organizing the public consultation for Law 765 and continues to play a – if not the – central role in national agroecological development (Landero et al. 2016) (*normative anchoring*). GPAE was also instrumental in promulgating Law 765 (*normative institutional anchoring*), and has recently begun to brand agroecological products for sale in stores in the larger cities (*economic institutional anchoring*) (Godek 2014; Gonzálvez, Salmerón, and Zamora 2015). Additionally, this period of agroecological amplification in Nicaragua has been very much premised on gender equity and women have largely become the face of agroecology in Nicaragua, which may be partially credited to INGO support for gender equity issues in agroecological movements (Holt-Giménez 2006; Mier Y Terán Giménez Cacho et al. 2018).

In the past decade, outlets for agroecological products has surged, evidenced by the growth of community-supported agriculture initiatives, new municipal farmers' markets, the opening of ecological and health-conscious stores, greater ease of access to agroecological products in existing stores, and national brands of ecologically produced foods (all: *economic institutional anchoring*). While many of these outlets have opened in direct response to government actions (e.g. the farmers' markets) or with NGO support, national consumers' increased purchasing power (due to government support for the business sector) and growing public awareness of negative environmental impacts of industrialized food production have simultaneously increased demand for agroecological products.

Since 2008, agroecology has been institutionalized in graduate degree programs of the National Agrarian University. Rural technical schools, demonstration farms, and community seed banks, organized by a variety of state and non-state institutions, bolstered farmer-to-farmer interactions and knowledge sharing (McCune 2016). A plethora of institutions have formalized databases of farmers' agroecological knowledge. Scientific congresses on agroecology and trade fairs for agroecological producers were organized by the National Agricultural Technology Institute (INTA) in 2016 and 2017 (all: *technological anchoring*).

The Agroecological and Organic Production Law (Law 765) was enacted in 2011, with the associated Nicaraguan Mandatory Technical Standard creating technical, financial, marketing, and institutional guidelines for agroecological production (GRUN 2011; 2012) (*normative anchoring*). Law 765 includes aspects of food sovereignty and security, which are linked discursively and legally (GRUN 2011). The enactment of Law 765 was a success for the agroecological niche, but stakeholders point to several problems with it and the Technical Standards. First, its combination of agroecology and organic production make it, as one interviewee described, a "Frankenstein" law (interview, March 7, 2018, Managua). This hybridism is problematic: the technical guidelines, which take into account international organic certification standards, are too specific to fully accommodate the site-specific needs of

agroecology. Second, the implementation of these plans remains murky, with institutions that are specified in Law 765 (e.g. for the development of a low-cost, public certification process) not yet functioning, mainly because they have not been financed by the GRUN's budget (Sánchez Gutiérrez, Vásquez Zeledón, and Ripoll 2017). Third, to capture as much stakeholder opinion as possible, the drafting of Law 765 involved the largest public consultation process ever held in Nicaragua. Afterwards, government officials sent the draft law to FAO for comments. The final wording of the law then reflected more FAO's definitions, understood by some stakeholders as a water-downed version of the definitions they had set forth in the original draft.

5.4.2 Discussion: Dynamics of niche-regime interactions

As Figure 2 illustrates, since its inception, the Nicaraguan agroecological niche has been linked to the agri-food system regime at different moments using all identified anchoring processes. Yet, the agroecological niche remains small in comparison, and the agri-food system regime remains locked into productivist social and technical values and defined by links to international agri-food industries and conventional industrial farming practices. Although the agroecological niche has influenced the regime to the point of inducing legislative change, further substantial structural change has not occurred. The regime's embrace of agroecology remains discursive, without substantial implementation of stated goals. Particularly the lack of an assigned budget for agroecological initiatives, including those specified in Law 765, has meant that financing for agroecological projects has remained mainly in the hands of INGOs and international donors (as also described by Mier Y Terán Giménez Cacho et al. (2018)). This raises questions concerning financial autonomy in Nicaragua's agroecological transition. Compounding this are issues of international free trade agreements and a lack of pricing policies, which make profit margins so little that transitions to agroecology come at great risk, particularly to poorer farmers.

Looking at actors and networks, two main camps can be identified: government-associated institutions and projects funded by the state, and CSOs and initiatives typically funded by international NGOs. Although sometimes actors overlap, these camps follow distinct objectives and discourses and are generally fragmented. Few incumbent actors have reoriented incrementally towards agroecology. Concerning technologies, agroecology has mainly been used by the agri-food system regime as a tool to develop smallholder production. Agroecological practices have been incorporated into the industrial agriculture-based agri-food system regime, but without impacting incumbent practices. Institutionally, the addition of agroecology and related food and nutritional sovereignty and security frameworks into government policies is an important step in legitimizing agroecology in the agri-food system regime. Yet, the regime's weak implementation of many of these initiatives questions how effective this legislation is at prompting change.

The fragmentation of discourse within the agroecological niche has weakened its potential bargaining power vis-à-vis the agri-food system regime. The agroecological movement has sustained incremental work on an agroecological transition for several decades. The state is a more recent entrant. It has successfully co-opted ideas from the movement to further its agenda. Several examples illustrate how the agri-food system regime's discourse has come to subordinate the agroecological niche's discourse. First, since 2007, the regime's 'big tent' approach to agricultural development means that all farmers, regardless of land-holding status or farm size, are treated by the same laws (Ripoll 2018). In practice, this means that the government accommodates different kinds of approaches to agricultural production, from extractivist practices to agroecology. By discursively including all farmers and claiming to address all farmers' needs, the regime co-opts the debate around agroecology (cf. Ripoll (2018). Second, the regime's co-optation of the agroecological discourse is clearly reflected by the process of writing Law 765, discussed above. Such "hijacking" of discourse has been noted in the global debate on sustainable food systems (Mockshell and Kamanda 2018).

5.5 Conclusion

This study has analyzed the factors hindering the agroecological transition in Nicaragua by exploring processes of niche-regime interactions. We found that the agroecological movement has succeeded in strengthening the niche and anchoring into each of the distinct agri-food regimes over the last several decades. Furthermore, agroecology has been supported by the state through its recent adoption in national policy; however, at the same, the hybrid approach of the government to food and agriculture policy has limited agroecology's broader societal institutionalization and impact on agri-food regimes owing to the continued reproduction and subsequent (re)legitimation of neoliberal, industrial agricultural policies and practices. Although examples of all four kinds of anchoring abound, the regime's influence over the niche has led to a subsuming of the niche into the regime. This is particularly visible when discourse dynamics are analyzed.

This study raises abundant questions for future research on agroecological transitions. Four areas are of particular importance. First, niche actors are heterogeneous and diverse; they collaborate in some ways but lack synergy in others. Who collaborates when and why, and how can collaborations best be supported to enact transitions? Considering there is some overlap between niche and regime actors, richer analysis is needed on the roles and functions of these hybrid actors in enabling agroecological transitions. Second, regarding climate-dependent socio-technical systems such as agriculture, bioregional and climate dynamics are crucial elements that are often not sufficiently integrated into analyses. How can such dynamics be better integrated into frames analyzing socio-technological transitions? Third, recent criticism of the MLP framework for not challenging neoliberal free market dynamics (Feola 2019) speaks to fundamental questions of sustainability in capitalist systems. The

addition of political ecology to the analytical framework offered by MLP may be useful for better understanding such fundamental issues. Fourth, as MLP theory has been criticized for not paying enough attention to issues of power (Köhler et al. 2019) and to the role of the state in transitions (Johnstone and Newell 2018), the addition of the discursive element is promising for future studies to more deeply pinpoint the power struggles between the niche and the regime. In particular, further research is needed on discourse fragmentation within the niche and its impact on fundamental systemic changes, especially when confronted with the strength of the industrial agri-food system paradigm.

Chapter 6: Discussion and synthesis

6.1 Introduction

Transforming agri-food systems to more sustainable modes of production and consumption is becoming more and more urgent in the face of the climate crisis (Springmann et al. 2018). Agroecology, or the ecology of agri-food systems, can be part of the solution towards more resilient, productive, and fair agri-food systems (Wezel et al. 2020; Bezner Kerr et al. 2021). Although scientific knowledge on agroecological transitions has increased in recent years, a systematic framework for understanding and comparing agroecological transitions has not yet been implemented. Contributing to this discussion, this thesis has employed socio-technical sustainability transitions theory to structure our understanding of agroecological transitions. Through chapters 2, 3, 4, and 5, the thesis has both explored (documented) and explained (analyzed) the emergence and development of the agroecological transition in Nicaragua.

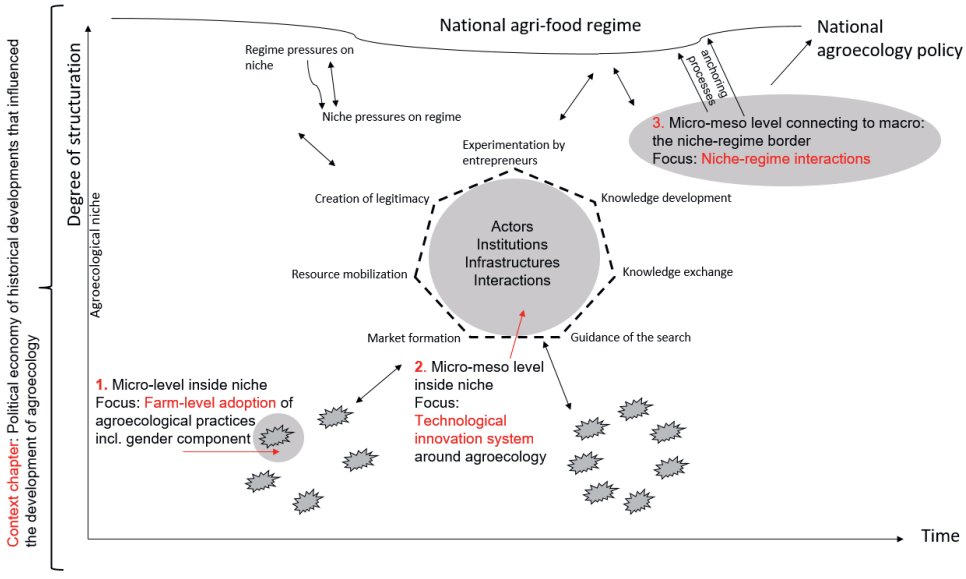

Figure 28: Loci of the chapters and research questions in the development of the agroecological niche

The thesis has investigated Nicaragua's agroecological transition through an in-depth exploration of the development of the agroecological niche using a conceptual framework based on socio-technical sustainability transitions theory. Figure 28 illustrates the loci of the chapters and research questions within the conceptual framework. A context chapter documented the historical and political economy background that influenced the development of Nicaragua's agroecological transition. As demonstrated in Figure 28, the agroecological niche was examined from three perspectives: (1) that of central agricultural change agents, i.e. farmers; (2) from a structural-functional perspective concerning the development of actors, networks, institutions, and infrastructures; (3) through a processual perspective

examining how the niche has anchored into, and to what extent it has changed, the national agri-food regime. These perspectives correspond to three different conceptual loci: (1) inside the niche at the micro-level of individuals enacting transition processes; (2) inside the niche at the micro-meso level of individuals and organizations interacting to support agroecology; (3) at the niche-regime interface, or where the micro-meso level connects to the macro level. Each perspective used a different theoretical lens to explore the research question: (1) adds a social psychology and gender angle to the socio-technical framework (Upham, Bögel, and Dütschke 2019); (2) uses Technological Innovation Systems (TIS) analysis (Hekkert et al. 2007; Bergek et al. 2008); (3) focuses on anchoring processes through which niches attempt to change regimes (Elzen, Van Mierlo, and Leeuwis 2012; Bui et al. 2016). Together, these three perspectives provide a holistic analysis of the development of the agroecological niche in Nicaragua. Zooming out to the 'big picture' offered by the synthesis of the analyses allows additional conclusions to be drawn.

This chapter summarizes and synthesizes key findings of the thesis and the broader contributions of this research. First, I deepen the discussions of the findings from each chapter relating to the thesis' research questions (section 6.2). Next, I discuss the wider implications of these findings for scientific and societal debates (section 6.3), including recommendations for policy-making and practitioner work (section 6.4) and suggestions for future research (section 6.5). In section 6.6, I reflect on the implementation of research and on my role as a researcher. The thesis concludes with final reflections that capture the study's main lessons learned.

6.2 Deepening the discussion of the main findings

In this section, I deepen the discussions of the findings of each of the empirical chapters. Following this, in section 6.3 I reflect on cross-cutting issues that emerge from taking the findings together before discussing the broader implications of the findings as regards theory, practice, and policy in section 6.4.

The primary focus of the research was the agroecological transition in Nicaragua. A detailed context chapter (Chapter 2) provided a historical and political economy-focused background on Nicaragua's agri-food system. The three empirical chapters (Chapter 3, 4, and 5) each addressed one of the research questions, which conceptually zoomed out from the micro-level of individual actors on farms, to the micro-meso level of what was going on inside the new agroecological niche as it developed, to the meso-macro level of how the niche engaged with the regime in its attempts to foment wider systemic change (as shown in Figure 28). The following over-arching research questions were addressed (conceptual levels addressed are in italics):

> RQ 1. How do personal norms and gender influence farmers' adoption of agroecological practices? (*Micro level*)

RQ 2. How do actors, networks, infrastructures, and institutions interact over time to develop an agroecological transition? (*Micro-meso level*)

RQ 3. Through which processes do actors and institutions try to link into the regime to effect change towards agroecology in mainstream agri-food systems? (*Meso level connected to macro*)

In this section, I respond to these questions using the findings of Chapters 2, 3, 4, and 5.

6.2.1 Looking at individuals: Gender and pro-environmental personal norms in farmers' adoption and use of agroecological practices

To answer the first research question, I surveyed 121 smallholder farmers in northern and central Nicaragua using a two-part survey: the first part regarding their adoption and use of agroecological practices, and the second part consisting of questions frequently used in social psychology research concerning people's enaction of pro-environmental practices. Chapter 3 answers this research question.

Recently, social psychology has been explored as to what its insights could yield to better understand the individual and collective actions of people 'enacting' sustainability transitions in their daily lives through pro-environmental behaviors (Bögel, Upham, and Castro 2019; Upham, Bögel, and Johansen 2019). Chapter 3 contributes to this discussion, adding a gender dimension to the question of individuals' motivations to enact pro-environmental behaviors. Examining Nicaraguan farmers' pro-environmental personal norms and their adoption of agroecological farming practices, I found that a high rate of female farmers tended to adopt a large amount of such practices regardless of the strength of their pro-environmental norms, while in male farmers, stronger pro-environmental personal norms tended to predict stronger adoption of agroecological practices. The study contributes to the nascent discussion in sustainability transitions research concerning individuals' pro-environmental norms as important drivers of their pro-environmental behavior.

The farms of both female and male farmers, regardless of their gender, were highly biodiverse both spatially and temporally. While almost all farmers had adopted practices such as agroforestry and the use of native seeds, the practice of soil inoculation with mycorrhiza was by far the least-used among the farmers who participated in the survey. During many farm visits, I observed farmers (particularly women) making bio-fertilizer from on-farm products, which then fermented for some months; I did not observe anyone using simple techniques to multiply soil mycorrhiza. During talks and meetings with extension agents and staff from agrarian universities, this subject was not addressed either. Strengthening the application of the practice of multiplying soil mycorrhiza on-farm, for use as a bio-input, could be relatively easily integrated into Nicaraguan extension programs and is a simple entry point to increase soil health and crop yields in agroecological farms.

This chapter contributes to a number of debates concerning agroecology and socio-technical sustainability transitions. Regarding agroecology, it contributes to the extensive literature on agroecological practices and their use by smallholder farmers and the scarce literature on farmers' values and norms in relationship to their adoption of agroecological practices (Wezel et al. 2014; Paracchini et al. 2020). Agroecological farmers' values and norms are often implicitly assumed to be pro-environmental, but little research exists that explicitly addresses this.

In wider socio-technical transition studies, social psychology has been used primarily in relationship to consumption and technology acceptance (Bögel, Upham, and Castro 2019), with the literature instead emphasizing various forms of collective agency (Upham, Bögel, and Johansen 2019). Attitudes and behaviors - particularly identity and lifestyle aspects - are often cited as key drivers of pro-environmental behavior and highly relevant in transitions research, but without connection to psychological theories or empirics (Upham, Bögel, and Johansen 2019). Yet, behavioral insights have become an important discourse influencing policy-making and offer large potential as a site for boundary-spanning work and translation between research and policy to help accelerate transitions (Kaufman et al. 2021). The findings confirm this and support work highlighting the importance of taking into account social psychological factors influencing individuals' behaviors in transition processes, including project planning and policy formulation (Janssen, Beers, and van Mierlo 2022).

The chapter's findings contribute to gaps concerning questions of gender in both agroecological and socio-technical sustainability transitions literatures. Chapter 3's results point to differences in men and women's pro-environmental personal norms that may be mobilized in e.g. sustainability initiatives and supports research showing that gender mediates participation in transition processes in many forms, which may be expressed as institutionalized norms or oppressive power relations, as masculine norms and gender regimes dictate planning and implementation of transition processes (Kronsell 2013). As such, gender links landscape-level issues like social norms, including gender relations, with the micro-level of individuals, their daily practices, and their enactment of transformative behaviors that support transition processes. The links between gender as a social construct and norm, its related questions of who has shaped institutionalized norms and so built power (imbalances) into systemic structures, and how these impact on individuals' everyday practices and engagement with sustainability transitions, are sure to be addressed by future research on sustainability transitions studies. Recent reviews show that research on gender in socio-technical transitions is increasing and gaining increasing salience in the field (Truffer et al. 2022). Concerning agroecology, the findings highlight the need for a stronger focus on gender-responsive agroecological discourses, policies, and research (Akram-Lodhi 2015; Park, White, and Julia 2015).

6.2.2 Inside the niche: Structural-functional analysis of the agroecological transition

The second research question was answered mainly in Chapter 4, and the findings reflected based on historical developments detailed in Chapter 2. I used a TIS lens to investigate the interactions between actors, institutions, and infrastructures and how these may hinder or drive the agroecological transition. The structural-functional analysis in Chapter 4 revealed several central issues currently hindering the agroecological transition: particularly policy mismatches, the inadequate mobilization of resources, and insufficient market development were shown to be factors that lessen entrepreneurial opportunities and experimentation. In a second step, specific barriers underlying these issues were pinpointed. Three central conditions were ascertained: (i) hard and soft institutional problems that limit entrepreneurship and experimentation and (ii) only weak creation of legitimacy for agroecology, with the core problem identified as (iii) the lack of a common vision for the development of agroecology in Nicaragua.

Contributing to the literature on failures in socio-technical sustainability transitions, on a theoretical level the findings provide a rich picture of the four so-called transformational failures, which go beyond the traditional rationales of market and structural systems failures (Edler et al. 2021). Identifying the four transformational failures - directionality, demand articulation, policy coordination, and reflexivity failures - can legitimate rationales for policy interventions in processes of transformative change such as agroecological transitions (Weber and Rohracher 2012). The case study shows that besides the central role of the state, other actors such as civil society may enact processes that overcome systemic failures. On a theoretical level, the example from Nicaragua shows that while directionality, policy coordination, and reflexivity failures are strongly driven by government (in)action, other social forces such as civil society can take central roles in articulating demand and hence drive transition processes from this angle. It points to the importance of taking into account discursive power and its implications for shaping transition processes, as discussed in the next section.

Table 17 gives an overview of how three of the four transformational failures are embodied in Nicaragua's agroecological transition. While the directionality and policy coordination failures are strong, reflexive failures are less pronounced. This can be linked to the historically important role given to farmers and farmer cooperatives in Nicaragua during and after the Nicaraguan Revolution, and to strong roles that civil society and its organizations have taken in the scaling up - the anchoring at higher institutional levels - of agroecology, also in political spheres. Demand articulation failure does not really exist in Nicaragua - on the contrary, farmers' organizations and civil society have done an excellent job in listening, understanding, and articulating heterogeneous stakeholders' demands for agroecology. Many spaces exist, at different administrative levels and in different geographic areas of the country, for learning about user (mostly farmers) needs; the national agroecological associations and networks have worked hard, and with success, to articulate and amplify these. Responding to this demand, for example agroecological degree programs at national universities continue to grow in number and in

number of students graduating. Implications for policy supporting agroecology in Nicaragua and beyond are discussed below in section 6.4.

Table 17: Transformational system failures in Nicaragua's agroecological transition

Type of failure	Failure mechanism
Directionality failure	• Lack of a shared vision regarding the goal and direction of the agroecological transition • Only weakly implemented and enforced regulation and standards to guide and consolidate direction of change • Lack of targeted funding for research and infrastructures
Policy coordination failure	• Incoherence between policies at different administrative levels and across sectors • Weak vertical coordination between ministries and implementing agencies • Mediocre horizontal coordination between research and innovation policies and sectoral policies for agriculture and food • Weak coherence between policies and private sector institutions
Reflexivity failure	• Weaker failure than the other two: multiple distributed reflexive spaces exist that connect different discursive spheres, and provide space for experimentation and learning between different stakeholder groups • Weak in adapting policy portfolios to keep options open and deal with uncertainty

Contributing to the literature on agroecological transitions, the case study demonstrates the analytical power of the TIS perspective and a broader view on systemic failures. The addition of such a perspective to analyses using food regime theory, which specifically takes into account historical power relations to understand modern agri-food systems and which is widely used in the agroecological literature, could provide a more nuanced evaluation of why entrenched agri-food regimes remain in power and specific action points to support regime change.

6.2.3 The niche-regime interface: Anchoring in to effect regime change

The third research question probed into the processes through which the agroecological niche has tried to link itself into regime structures in its attempt to effect regime change. Chapter 5 answers this research question using the concept of 'anchoring' to explore the processes through which niches act at the niche-regime interface in their quest to embed themselves into the regime (Elzen, Van Mierlo, and Leeuwis

2012). Insights from Chapters 2 and 4 further refine the analysis. In addition to the three forms of anchoring identified by Elzen, Van Mierlo, and Leeuwis (2012) (through technologies, through networks, and through institutions) I explored discursive anchoring, as the creation of shared discourses and joint vision-building have been highlighted as key processes enabling niches to embed into regimes (Bui et al. 2016). The findings reinforce the importance of paying attention to discursive anchoring and beyond that emphasized the power of discourse in transition processes. Although the agroecological niche has succeeded in linking to the national, conventional agri-food regime technologically, institutionally, and, arguably most strongly in terms of real-world impact, through networks, the fragmentation of discourse between agroecology and organic agriculture has been and continues to be a defining factor shaping the agroecological transition and its possible future pathways. These findings contribute to the literature on the discursive space created within niches (Leeuwis and Aarts 2011; Pesch 2015). Niches are spaces in which the meanings and significance of innovations are contested by heterogeneous stakeholder groups. As such, they offer more discursive space than do regimes (Pesch 2015). The findings nuance the importance of two discursive elements considered quintessential in niches: expectations from stakeholders, and their visions of how to enact their expectations. The Nicaraguan case shows that while stakeholders may have similar expectations (e.g., the construction of robust, productive, environmentally friendly agri-food systems that increase food security and nutrition outcomes), their visions of how to get there diverge (i.e., organic or agroecological agriculture) - and yet the niche actors have succeeded in creating a unified story vis-à-vis the regime. This has created discursive space within the regime itself concerning ecological agriculture and strongly informed the formulation and enactment of policy in support of agroecology and organic agriculture.

Since the publication of Chapter 5, an interesting new development has happened concerning the discursive linking of agroecology into the national agri-food regime. The national council of universities, which does not hold political power but is closely linked to the government in the current Nicaraguan political system, has coupled agroecology to the growth of small- and medium-sized agro-industry, framing them as complementary strategies to drive rural development and increase food security (Rojas Meza, Chavarria Aráuz, and Salazar Centeno 2021). The development of small- and medium-sized agro-industries, in a decentralized manner and throughout the country, are seen as crucial to provide the bio-inputs necessary, but currently lacking, to significantly scale up agroecological production (as detailed in Chapter 4). It remains to be seen how and to what extent this proposition will be picked up in government policies and programs.

An interesting factor in niche-regime interactions in the Nicaraguan case, not further explored in Chapter 5 but warranting further investigation, is the fluidity between individual niche and regime actors. Such fluidity between niche and regime has been captured in the concept of hybrid actors (Elzen et al. 2011). Many of the influential players in Nicaragua's agroecological niche are, were, or will be employees of the government and hence inside the institutional heart of the national agri-food regime itself. Due to their roles within both the niche and regime, these actors play crucial functions in transition processes

(Parag and Janda 2014). Based on shared values, their interactions and dynamics create new possibilities that shape transition pathways (de Haan and Rotmans 2018). For a more nuanced view on these actors that overcomes the niche/regime binaries, they can be seen as frontrunners (who early on make innovations known and available), connectors (crucial as intermediaries between actors and systems), topplers (who change and phase out institutions to make way for alternatives), and supporters (whose endorsement provides legitimization of and expresses the societal need for the innovation) (de Haan and Rotmans 2018). The extent to which these individuals are able to push for the inclusion of agroecological principles into official strategies, policies, and programs depends on multiple factors, including structural (e.g. in what level and institution their position is) and relational (e.g. previously accumulated influence and soft power) ones. The roles played by such individual, influential key players in navigating between the niche and regime are under-examined and raise many interesting questions, e.g. how they maximize their leverage in both niche and regime settings without losing legitimacy in either. This relates to discussions on the storylines and actions used by systemic intermediaries to legitimize their roles in transition processes (van Lente, Boon, and Klerkx 2020).

6.3 Cross-cutting issues: Wider implications of the findings

This section brings together the findings discussed above in section 6.2, synthesizing the main lessons learned and discussing cross-cutting issues. Taken together, the chapters of this thesis contribute to a better understanding of the dynamic processes of niche development in socio-technical sustainability transitions. Conceptually, this thesis explored niche dynamics at several different areas - the micro level of individual actors deciding to enact pro-environmental behavior; the micro-meso level of collective actors, organizations and institutions working to grow the niche; and the meso-macro level, examining the niche's pressuring of the regime. This section discusses overarching themes that emerged from stepping back to take a broader, integrative perspective on the findings of Chapters 2, 3, 4, and 5. The thesis findings contribute both conceptual and actionable knowledge concerning agroecological transitions that can be used to support on-going agroecological transitions, discussed in more detail in section 6.4. Figure 31 in section 6.4.2 synthesizes the main learnings and cross-cutting insights from the thesis.

The section provides further reflections on the thesis by positioning the conclusions in broader scientific and policy debates - in the discussions around agroecological transitions, in the debates on mainstreaming agroecology through policy, and in questions of sharpening the lens of socio-technical sustainability transitions theory so it is more applicable to diverse (national) contexts. In addition to empirical data and conceptual input for the agroecological and socio-technical sustainability transitions literature, overarching insights from the research point to the importance of transitions research taking into account intangibles that may be difficult to quantify, such as discursive power and the power to

shape formal and informal institutions. This section discusses the main themes that emerged from the thesis findings and from bringing together the agroecology and sustainability transitions literatures. Following this, section 6.4 synthesizes the suggestions that arise from this discussion for further developments in policy, practice, and research concerning agroecological transitions.

6.3.1 Bridging the literatures on agroecological and socio-technical transitions

Considering the three aspects of agroecology usually identified in literature - as a science, a practice, and a social movement (Wezel et al. 2009) - these are all, as the previous chapters have shown, strongly developed in Nicaragua. Based on the findings from the case study, I would argue for the inclusion of a fourth dimension, explicitly political agroecology, to these three aspects (see also (González de Molina 2013; Rosset and Altieri 2017; González de Molina et al. 2019; Anderson et al. 2021). Together, Chapters 4 and Chapter 5 showed that although the niche may link into and impact the regime to the point of effecting policy change, e.g. the passing of the legislation in support of agroecology, different barriers may impede the implementation of the new policy and contribute to the various transformational failures hampering the agroecological transition. Agroecology's further development, at the national institutional scale, is guided by the government. Yet, the signals given by the government are mixed: although agroecology policy exists, it is not backed up by the creation of related and necessary market infrastructures, nor by resource mobilization, that generate financial incentives for agroecological production. These contradictions posed by the state create confusion amongst stakeholders and undermine the creation of legitimacy for agroecology, and are a hindrance to the necessary demand-side experimentation. Both chapters point to questions of power in transitions, such as who - and when - has power in controlling discourse, power in institutional organization, and political power, and how this shapes possible different transition paths. Chapters 2, 4, and 5 highlight the central importance of discourse and the power of those who define discourses and delineate practices. Here, the socio-technical findings could be enriched by a food regimes perspective, which explicitly considers power in shaping food regimes (Holt-Giménez and Shattuck 2011; Anderson et al. 2021). Connecting to other work using a socio-technical perspective to understand agroecological transitions, these issues of power point to broader questions of rights (over resources, but also in processes) and, linked to this, inequalities that manifest themselves in transition processes, e.g. through overt discrimination, unequal access to resources, and unequal decision-making power (Anderson et al. 2021). Here, questions of gender that contribute to social differentiation and class formation, reproducing inegalitarian structures and resulting in unequal access to resources and decision-making, should also be systematically addressed (Park, White, and Julia 2015). Building systemic ethics (i.e. a systemic understanding of the problems and perspectives of sustainability, including social justice) and inclusive governance into transitions goals and processes should be key features of (not just agroecological) transitions programs and policies (Bui et al. 2019).

Continuing with the notion of the four aspects of agroecology, the findings highlight the importance of transnational linkages to support the development of agroecology as a science, practice, movement, and politically locally and globally. In the Nicaraguan case study, the findings show that the development of agroecology within Nicaragua and the development of agroecology globally both influenced each other through such transnational linkages of knowledge, people, and financial resources. By no means was agroecology within Nicaragua the weaker recipient in this relationship: Nicaraguan social movements and farmer organizations have profoundly shaped the theory and practice of agroecology, and influenced social movements towards agroecology, at the global scale (Godek 2014). This links to ideas of the 'glocalization' of systems - the unique articulations of practices that emerge in different geographic areas as global and local communities of practice link (Robertson 1995; Ritzer 2003; Roudometof 2016). While processes of glocalization are clearly happening in agroecology as a practice - as evidenced e.g. in the continued spread of agroecological practices in different geographies around the globe (Mier Y Terán Giménez Cacho et al. 2018; Toffolini et al. 2019) and in the coming together of local farmers' associations in the global, transnational organization La Via Campesina (Desmarais 2008) - they are rarely addressed in agroecological research: Much of the literature describes case studies of agroecology without identifying where these practices originated (e.g. traditional or innovative local farmers' practices, and/or external influences) and the modes through with they were appropriated, negotiated, and adapted in different areas (Thivet 2014). Here, a conceptual bridge can be built to the notion of global socio-technical regimes, which explores the multi-scalar interrelationships between actor networks and institutional structures in socio-technical transitions taking place in different geographies (Fuenfschilling and Binz 2018). While such global regimes have been understood as having stronger global-to-local than local-to-global dynamics, the Nicaraguan case demonstrates that local developments can also drive advancements at the global scale.

While the agroecological literature is strong on the central roles played by farmers, farmer organizations, and rural social movements in promoting agroecology (Rosset and Martínez-Torres 2012; Mier Y Terán Giménez Cacho et al. 2018), the case study highlights the importance of other individual actors, at higher administrative levels, who move between niche roles in supporting agroecology and regime roles as employees of government-affiliated organizations and have not yet been identified empirically or conceptually in the agroecological literature. Further, in Nicaragua, the main push for agroecology has come from grassroots movements, but one of the most important of these grassroots movements (the farmer-to-farmer program PCAC-UNAG) has from the beginning been associated with a regime actor, the farmer union UNAG. The case study demonstrates that a regime actor (UNAG) may incorporate a niche actor, as UNAG incorporates PCAC-UNAG. Understanding both individuals and organizations that are involved in both niche and regime activities as hybrid actors, as conceptualized in the socio-technical transitions literature (and discussed above in section 6.2.3), and analyzing their actions in leading, connecting, toppling, or supporting transition processes (de Haan and Rotmans 2018) could enable practitioners and researchers in agroecology to more clearly identify and support such actors in

their efforts to enable transitions. Hybrid actors are fluid in that they embody sets of societal values across their different roles, and contribute to diverse network activities in support of transitions (de Haan and Rotmans 2018). Due to their situations between different levels - niche and regime - and between different stakeholder groups, such actors play crucial roles in transition processes (Parag and Janda 2014). Beyond their intermediary functions - between stakeholder groups and conceptual levels - hybrid actors can foment a 'middle-out' approach that lies between top-down and bottom-up strategies (Parag and Janda 2014). The case study's identification of not just organizations, but individuals who embody hybrid positions and strongly contribute to transition processes begs the question of focusing on individuals, their agency, and their power in agroecological and socio-technical sustainability transitions research, which have both hitherto explored the power of social processes rather than individuals.

Continuing with the literature on the important roles grassroots innovations may play in furthering sustainable agri-food transitions, the case study shows that civil society organizations can alleviate transformational system failures, such as demand articulation failure, whose articulation the socio-technical literature sees as strongly in the realm of the state (Weber and Rohracher 2012). Although the state must take the central role in ultimately fostering a conducive framework for agroecology, this illustrates the power of grassroots and civil society movements in fomenting transitions. In the Nicaraguan case, hybrid actors such as PCAC-UNAG also function as part of the grassroots movement and hence the importance of their actions is not to be overlooked, also concerning questions of glocalization of agroecology. Connecting to the literature on multi-scalar dimensions of grassroots innovations (Hermans, Roep, and Klerkx 2016), as Figure 29 elucidates, the case study demonstrates that the grassroots, local push for agroecology in Nicaragua has succeeded in influencing agroecology's spreading and diffusion at a global scale spatially, and through the broad and deep connections it has made to other organizations and networks regionally, nationally, continentally, and globally. Considering the dimensions of politics and power, grassroots innovation in agroecology in Nicaragua has, interestingly, influenced administrative scales at national and Central American scales more than at municipal and departmental scales, through aspects such as transnational peasant organizing and standard-setting for organic products throughout Central America. This points to a policy mismatch concerning administrative scales, and highlights the necessity of integrating the municipal and departmental scales in addition to the national scale.

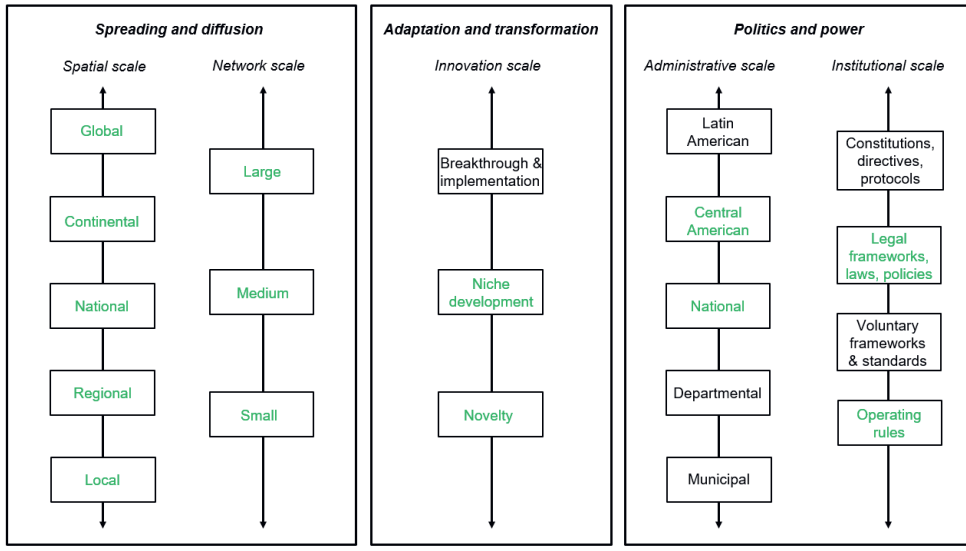

Figure 29: Dimensions (across top) and scales of grassroots transitions (based on Hermans, Roep, and Klerkx 2016). Text in green indicates strong articulation through grassroots activities in Nicaragua's agroecological transition.

The case study confirms the importance of individual and social learning and of knowledge co-creation processes by diverse stakeholders to advance transition processes. While the socio-technical transitions literature emphasizes the importance of learning and experimentation around innovations, the agroecology literature is much richer in terms of the central importance of peer-to-peer processes, learning-by-doing, and knowledge co-creation by heterogeneous stakeholders to support transitions to agroecology (McCune and Sánchez 2018; Rivera-Ferre et al. 2021; Utter et al. 2021). The findings demonstrate the importance of learning and knowledge creation around agroecology by a range of different stakeholders besides farmers, such as government officials at various administrative levels, rural development initiatives, consumers, and universities. They contribute to a more nuanced view of learning in transitions, including the incorporation of non-formal knowledge, horizontal learning pedagogies, and peer-to-peer approaches, and the involvement of a broad diversity of stakeholder groups. Linking to the discussion of glocalization above, insights from the case study also provide empirical examples of and speak to conceptualizations of how knowledge is transferred between local and global scales. Locally generated experiences and situated, tacit knowledge must be accumulated and transformed into written, generic trans-local knowledge that is codified and can travel between different contexts at a global scale (Geels and Deuten 2006). This process of knowledge aggregation has happened in Nicaragua, and has been particularly influential concerning the development of the global farmer-to-farmer movement, transnational peasant organizing, and standard-setting at a regional scale.

6.3.2 Reflecting on mainstreaming agroecology through policy

As the Nicaraguan case demonstrates, the mainstreaming of agroecology into the dominant agri-food regime through policy is a process fraught with contradictions. A nuanced analysis showed that both individuals and organizations connected to the regime can take hybrid roles, in which they support the agroecological niche while part of the regime. Four issues were highlighted by the case study. First, the findings underscore the heterogeneous strategies incumbent actors may enact as techno-economic, socio-political, and institutional circumstances, and associated resources and challenges, change over time (Turnheim and Geels 2013; Steen and Weaver 2017). Second, they point to the central importance taken by individuals and organizations that can navigate in the grey area between niche and regime, acting as translators and intermediaries between the two (Klerkx and Aarts 2013; Kivimaa, Boon, et al. 2019; Kivimaa, Hyysalo, et al. 2019). Third, they hint that by participating in the institutionalization of agroecology, alternative food movements and civil society organizations may become part of the established rules of the game - the regime - and hence participate in the reproduction of incumbent dispositions (Giraldo and McCune 2019; Turnheim and Sovacool 2020). Fourth, the findings demonstrate incumbent actors' capacities to absorb sustainable alternatives without changing the dominant regime structures (Späth, Rohracher, and Von Radecki 2016). This supports arguments to pluralize the understanding of incumbencies in socio-technical sustainability transitions (Turnheim and Sovacool 2020) and to resist the temptation of portraying socio-technical regimes as monolithic (Stirling 2011).

Taking a broader view, the findings show that the scaling up of agroecology - its anchoring into the national institutional framework - may also complicate its enactment as originally envisioned by its proponents. This is perhaps illustrated most clearly by the dual focus of the Agroecology and Organic Production Law. These findings speak to the wider debate on the conventionalization of farming practices, which has thus far focused on the organic farming sector (Darnhofer et al. 2010; Nikol and Jansen 2021). The conventionalization debate critically discusses two issues: how to characterize the mainstreaming of organic agriculture into, as some have argued, agri-industrial structures with large-scale, organic, mono-cropping, and whether this mainstreaming is problematic or not (Lockie and Halpin 2005; De Wit and Verhoog 2007; Darnhofer et al. 2010; Nikol and Jansen 2021). The example of organic agriculture shows that while symptoms of conventionalization - e.g. intensification, specialization, economies of scale, longer value chains, and growth increasingly driven and controlled by agribusiness - can be observed in agri-food systems around the world, this does not necessarily undermine the transformative potential of the organic approach, and that a diversity of organic production pathways can exist simultaneously (Nikol and Jansen 2021). Similar discussions around agroecology have often taken a more heated tone, with discourses revolving not around the conventionalization but more often, the co-optation of agroecology (Altieri and Holt-Giménez 2016; Laforge, Anderson, and McLachlan 2017; Migliorini and Wezel 2017; Anderson et al. 2021). Scientists, food system actors, social movements, and governments have diverging views about whether social and political dimensions of

food production should be considered integral parts of agroecology, critical for agroecology to be transformative (Méndez, Bacon, and Cohen 2012; Giraldo and Rosset 2017; Laforge, Anderson, and McLachlan 2017; Rivera-Ferre 2018; HLPE 2019a; Anderson and Maughan 2021). While Nicaragua's agroecology law recognizes agroecology's social principles, it focuses on the technical implementation of agroecological practices and market development for agroecological products as the main instruments for scaling agroecology nationwide (GRUN 2011). Looking just at the agroecology law, the Nicaraguan case suggests that mainstreaming agroecology through policy may hence be a double-edged sword: while it can increase the hypothetical resource base for agroecology (in terms of government spending on e.g. agroecological research, extension, and market-building activities), it can also lead to the dilution of agroecological principles, particularly those concerning social aspects. Yet, looking at the agroecology law as embedded in the broader national policy context which is evolving over time, social and political aspects of agroecology can be seen to have been (more or less explicitly) integrated into policies concerning different, but related, subjects such as family agriculture and micro-business development. As agroecology itself is multi-faceted (as a set of farming practices, a science, a social movement, and political agroecology), it makes sense to integrate different aspects of agroecological principles into different policy fields. While some authors have suggested clearly distinguishing between a political agroecology, which considers political and social factors to explicitly address broader issues of food security and nutrition, and a technically-focused agroecology at the farm scale (Méndez, Bacon, and Cohen 2012; Bellamy and Ioris 2017), the findings of the thesis suggest that rather, agroecology needs to be understood as dynamic, i.e. as a system that responds to internal and external demands and conditions. This means that, instrumentalizing agroecology's diversity of aspects, its principles should be integrated into not just agri-food-focused but also other policy spheres, e.g. market-development related, social, or public procurement policies. Further suggestions for supporting agroecology through policy are given in section 6.4.1.

6.3.3 A more nuanced understanding of the factors shaping socio-technical transition pathways

An integrative analysis of the findings of chapters 2, 3, 4, and 5 suggests that the agroecological transition in Nicaragua has so far undergone three stages, as illustrated in Figure 30. In the first stage, agroecology formally emerged through interactions between international and local actors and structures; its emergence was strongly shaped by the socio-economic-political situation in Nicaragua in the 1970s and 1980s, with farmers and farmer cooperatives playing central roles in increasing agroecological practices and legitimizing agroecology as an alternative to conventional agriculture. In the second stage, from roughly 1990 to 2006, the dynamics of the agroecological niche shifted as state funding for agriculture and social programs waned; international funders stepped into the gap and a plethora of national NGOs working with agroecological principles and practices were formed. Since the

mid-aughts, a third stage can be identified, in which civil society's and actor networks' power has grown, formal higher education for agroecology began to be mainstreamed into several national universities' curricula, and market creation aspects began to be addressed. Aggregating lessons learned from Chapters 2, 3, 4, and 5, Figure 30 illustrates a multi-level perspective on main organizations and events that informed agroecology's development at niche, regime, and landscape levels.

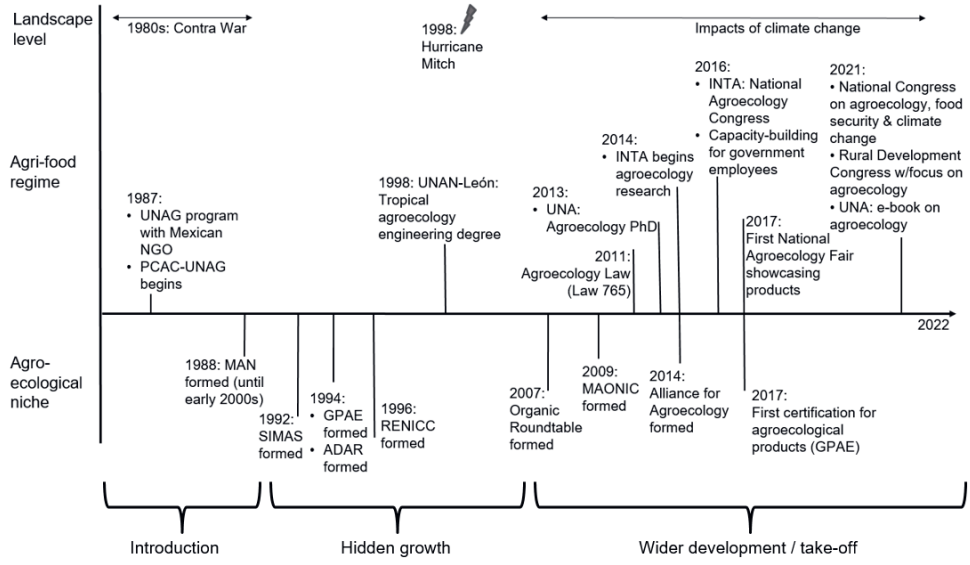

Figure 30: Aggregated analysis: A multi-level analysis of important actors and events in the three stages of Nicaragua's agroecological transition

Connecting to work on the phases of transitions, the empirical findings point to the non-linearity and heterogeneity of transitions processes and call for more flexibility concerning the four phases of transitions as commonly framed in the literature (see e.g. Geels 2019). The first phase is characterized by experimentation and trial-and-error learning by multiple stakeholders around radical niche-innovations (Geels and Schot 2007). Niche-innovations are protected through state actions (Roesler and Hassler 2019) or through more disparate issues such as cultural norms (Ortiz, Vilsmaier, and Acevedo Osorio 2018), but high uncertainties, competing claims and promises, and high rates of failure shape this first phase (Geels 2019). In the second phase, innovations establish a foothold in one or more market niches, securing a more reliable flow of resources (Geels 2019). The innovation stabilizes into a dominant design and new knowledge (e.g. best practices, design guidelines) begins to be codified, standardized, and abstracted while new stakeholders, such as consumers, begin to experiment with the innovation (Geels 2019). The third phase, in which the innovation diffuses into mainstream markets, is often characterized by struggles between the innovation and the regime on multiple dimensions (e.g.

economic, business, political, cultural) (Geels 2019). While structural windows of opportunity may open if landscape developments concurrently pressure the regime, innovations may suffer setbacks and fail to build up sufficient momentum to effect deeper regime change (Geels 2019). If the innovation does succeed, the transition moves to a fourth phase, in which the innovation's socio-technical system replaces (parts of) the old one and becomes institutionalized politically, technically, and socially (Geels 2019). The Nicaraguan case study shows that, rather than happening in a linear fashion, elements of later phases can manifest in earlier ones - for example, the political institutionalization of agroecology happened prior to stronger changes in market entrance. Socio-technical theory should also account for such hybrid patterns of phases of transitions. The findings support the argument for a more nuanced understanding of transition pathways and the fluidity with which they develop (de Haan and Rotmans 2018).

Further, the socio-technical literature on transitions taking place in areas in the Global South has suggested that rather than just transferring frameworks developed in the Global North, such as the socio-technical perspective, to the Global South, such frameworks should be refined to better account for contextual differences, including the roles of informal economies, splintered regimes, and multi-scalar insecurities, that strongly inform individuals' daily practices and general transition pathways (U. E. Hansen et al. 2018; Ramos-Mejía, Franco-Garcia, and Jauregui-Becker 2018; Wieczorek 2018; Ghosh et al. 2021). The findings of the thesis support this and point to several ways in which the refinement of socio-technical sustainability transitions theories for application in non-Global North contexts could serve to make analyses more sensitive to nuanced differences in transitions in these contexts, and hence increase the theory's explanatory capacities (U. E. Hansen et al. 2018; Ghosh et al. 2021; Preuß et al. 2021). Two sets of changes are identified in the literature and corroborated by the findings of this thesis: (i) changes in the TIS functions; and (ii) the explicit consideration of a set of influential factors at the landscape level, in which an additional factor is added based on the findings from this thesis. The consideration of landscape factors links to literature suggesting a broader conceptualization of innovation ecosystems (Pigford, Hickey, and Klerkx 2018).

Considering changes to TIS functions, the findings support Edsand's (2019) suggestions of three changes to the generally considered TIS functions (as detailed in Chapter 4; see also Bergek et al. 2008 and Hekkert and Negro 2009). First, amending the function 'creation of legitimacy' to include informal advocacy coalitions. Splitting creation of legitimacy into formal (large, well-established, well-funded groups with political and economic weight) and informal (smaller groups or individuals) advocacy coalitions reflects the rise of internet technology as an important forum for shaping public opinion (Edsand 2019). Second, broadening the function 'knowledge development' to include not just the current absorptive capacities, but to explicitly include a country's adaptive capacity (its human, institutional, and organizational capacity to support the innovation (Edsand 2019)). A country's human, institutional, and organizational resources are often implicitly assumed to be able to absorb and assimilate new knowledge, yet a lack of adaptive capacity has been shown to be a hindrance in the development of

emerging economies (Saravia-Matus and Saravia-Matus 2009; Suzuki 2015), particularly in the scaling of agroecology (Pant 2014). Third, splitting the function 'resource mobilization' according to their origins, i.e. differentiating between international and national (financial) resources (Edsand 2019). International financial resources have been recognized as playing a different role in emerging economies than in industrialized ones (U. E. Hansen and Nygaard 2014).

The findings suggest that a closer consideration of landscape factors that strongly inform the development options for both regimes and niches may be important. The issue of landscape factors has been an area debated amongst TIS scholars (Geels and Schot 2007; Bergek et al. 2015; T. Hansen and Coenen 2015), with some authors arguing for including landscape factors in socio-technical analyses to better reflect different contexts (Coenen, Benneworth, and Truffer 2012; Gosens, Lu, and Coenen 2015). As seen throughout the thesis, contexts in the Global South, such as Nicaragua, may present different challenges than those captured by current conceptualizations of socio-technical transitions theory. Authors have argued that landscape pressures may be largest during the early TIS formation phase (Raven 2005), and that TIS in developing countries are more likely to be in a formative rather than a growth stage (Edsand 2016). The findings suggest that the following amendments, which have been identified by a small number of authors but not yet systematically addressed in the socio-technical sustainability transitions literature, could serve to fine-tune TIS analyses for applications not just in Global South contexts. Seven landscape factors have been identified and are detailed in the next paragraphs. Table 18 summarizes the proposed landscape factors and indicators.

Table 18: Suggested landscape factors, based on findings from this research and Edsand (2019) (indicators for all landscape factors also include effects on each other)

Landscape Factor	Indicators
Economic growth	Changes in GDP; domestic and international events
Environmental awareness	Changes in environmental awareness of actors; changes in societal trends
Climate change	Climate change related events & associated costs
Armed conflict	Cost of armed conflict (% of government expenditure); changes in entrepreneurial activities due to armed conflict
Corruption	Estimated loss in public resources (% of GDP); cancelled entrepreneurial activity
Inequality / access to education	Changes in access to higher education; mismatch between education and industry
Biophysical context	Climatic zone; location on continent; relationship to public goods (e.g. biodiversity & clean air)

Economic growth is implicitly assumed to be stable, if not increasing, in socio-technical theories. However, in Global South contexts, economic growth may be more variable from one year to the next, and may even be negative. Additionally, as the economies of many countries in the Global South are heavily dependent on the export of agricultural products, their economies are to a larger percentage exposed to world market prices for agricultural goods, which may fluctuate widely. Linking to insights from Chapter 3, the factor of environmental awareness reflects the social acceptance of the imperative of climate change impacts, and of changing (producer and consumer) patterns and behavior to be less harmful to the environment. This points to the importance of culture as an important factor both at the landscape level (in shaping general social trends) and at the micro-level of the individual, as cultural norms shape individual behavior (Litina, Moriconi, and Zanaj 2016; Blankenberg and Alhusen 2018). Data of the Climate Risk Index, which examines absolute and relative impacts of extreme weather events in terms of both human deaths and economic losses, shows that the impacts of climate change tend to be stronger countries in the Global South than in the Global North (IPCC 2015; Kreft et al. 2015; Wright, Huq, and Reeves 2015); as discussed in the thesis, Nicaragua is already experiencing these impacts. Armed conflict may impact entrepreneurial growth, human health and capacities, as well as the general economic development of the country. Further, it may have cross-sectoral and international implications, as seen in 2021's war in the Ukraine and ensuing disruptions in productive processes in Europe. The findings of the research suggest that, beyond armed conflict, the decline of democratic processes and the rule of law should be considered as well.

Corruption has long been known to be a detrimental factor for social and economic development, impacting negatively on entrepreneurial development, public revenue aggregation, inequality, and social trust among citizens, and increasing the costs of doing business (Lambsdorff 2003; Seppänen and Virtanen 2008; Gründler and Potrafke 2019). Although not explicitly discussed, the issue of corruption in Nicaragua strongly affects the agroecological transition, as actors associated with the government seek to maintain the status quo that enriches them (Seppänen and Virtanen 2008). The factor of inequality and access to education reflects the importance of knowledge creation for transition processes, and particularly the importance of knowledge creation by a broad cross-section of actors, not just elites. Regarding access to education, the Nicaraguan case suggests that access is not sufficient - rather, the quality of (primary and secondary) education also needs to be taken into account. Taking an agroecological perspective on TIS points to the need to include ecological and biophysical aspects into socio-technical frameworks. Clearly, biophysical factors fundamentally shape agri-food transitions, but other sectors (e.g. energy, construction, transport) are also deeply affected by environmental and ecological issues (Loorbach, Frantzeskaki, and Avelino 2017). Biophysical factors also relate to question of place-based embeddedness of innovations (and hence to the literature on geography of transitions (Raven, Schot, and Berkhout 2012; T. Hansen and Coenen 2015; Truffer, Murphy, and Raven 2015; Calvert et al. 2017)). The inclusion of biophysical factors in transition analyses would thus be an

important step to deepen such analyses' explanatory potential of past transitions, as well as very helpful to provide recommendations for on-going or ex-ante transition analyses.

6.4 Recommendations for policy, practice, and research

In this section, I reflect on questions for future policy-making, practice, and research for and on agroecology that are raised by the thesis findings.

6.4.1 Implications for policy and practice

From the cross-cutting analysis in section 6.3, four main issues can be identified that have implications for agroecological policy and practice. Different stakeholder groups have different options for actions they can take in support of agroecology and to address these different issues, summarized in Table 19.

Going back to the debate on mainstreaming agroecology through policy, the questions remains, how can agroecology be put into practice through policy without losing its human and social values? As the findings of the thesis suggest, here the diversity of agroecology could serve to integrate agroecological principles into multiple policy spheres besides targeted agri-food policies. This speaks to ideas of mission-oriented policies, through which governments aim to steer innovation systems to directly address grand societal challenges such as climate change (Klerkx and Begemann 2020; Wittmann et al. 2021). Drawing on agroecological principles and insights from research (as delineated in Chapter 1), the transition to an agroecological agri-food system could be adopted as an overarching, transformative policy mission. Extant knowledge on broader agri-food systems change, such as the levels of food system change (Gliessman 2015), the domains of food system transformation (Anderson et al. 2019), and the drivers of agroecological transitions (Mier Y Terán Giménez Cacho et al. 2018) can aid in identifying related (not agri-food) policy spheres in which agroecological principles could be enacted. By pinpointing agroecology as an overarching mission, deep and broad systemic change towards ecologically, economically, technologically, and socially sustainable agri-food systems could be driven by policy. As this goes directly against agroecology's grassroots character, it would be of critical importance to avoid capture by powerful regime elements (as argued in Chapter 5) (Smith, Fressoli, and Thomas 2014; Anderson et al. 2021; Clapp 2021; Montenegro de Wit et al. 2021; Bezner Kerr et al. 2022; Giraldo et al. 2022).

Besides an explicit law on agroecology, four policy instruments have been used across Latin America to mainstream agroecology into other sectors (Le Coq et al. 2020). First, instruments that manage innovations and new knowledge concerning agroecology, and aim to build farmers' and others' capacities for managing farms and territories according to agroecological principles (Le Coq et al. 2020). These often go together with networks for knowledge dissemination, such as Nicaragua's farmer-to-

farmer program. Second, instruments that facilitate access to land and water , such as land redistribution and legalization programs (Le Coq et al. 2020). Third, instruments targeting market creation and the regulation and promotion of products (Le Coq et al. 2020). These have two sub-types: programs for the marketing of agroecological products, including public procurement; and regulations and standards. Fourth, environmental regulation instruments and agri-environmental incentives, which can take a variety of forms (Le Coq et al. 2020). While environmental regulations can prohibit or regulate e.g. the use of certain phytosanitary products or land use, positive and direct economic incentives can support farmers and others in adopting agroecological practices that benefit e.g. the physical environment or biodiversity. Missing from this list are social policy instruments, which have not yet been directly used to further agroecology, but remain open to exploration and experimentation.

Even if agroecology is not enacted as an overarching, multi-faceted principle, but instead, as has been the case in e.g. Europe, focusing more on its technological and practical aspects (Migliorini and Wezel 2017), it can keep a part of its transformative potential. Even without its social and political aspects, agroecology's potential to contribute to the mitigation of climate change is transformative for our current, environmentally destructive agri-food system. While technologically-focused agroecology would clearly lose its ground-breaking transformative potential to push for fundamental societal changes (in terms of e.g. changes in distribution and access patterns or power relationships), it should nevertheless be part of the solution for moving towards environmentally sustainable agri-food systems.

Table 19: Identified issues and suggestions for actions by different stakeholder groups to address these

Issue	**Suggestions for actions by ...**		
	National governments	**Civil society**	**Private sector**
(Policy) mismatches & incoherence	• Review of policies informing the further spread and support of agroecology (i.e. not just agri-food policies, but also related ones such as those aimed at e.g. supporting small- and medium-sized enterprises or family businesses, or climate polices) at different administrative levels of government, and further, work on increasing the coherence of these policies across domains and levels	• Identification and development of synergies between agroecology and other sectors, e.g. ecotourism • Identification of novel synergies between smallholders and large farms within a region, e.g. the sourcing of manure (a product smallholder often lack) from large-scale livestock ranches for use as bio-fertilizer on smallholder farms	• Identification and development of synergies between agroecology and other sectors, e.g. ecotourism

Issue	Suggestions for actions by ...		
	National governments	**Civil society**	**Private sector**
	• Integration of true costs of agri-food production, including damage or benefits to public goods (e.g. pollution or enhancement of biodiversity), in economic models used		
Lack of knowledge on aspects of agroecology	• Strengthening of institutional knowledge on agroecological principles and practices through education of key government actors at different administrative levels, through special courses at national universities • Support for national extension services based on agroecology	Strengthening of information and knowledge-building on agroecological practices that are not practiced much by farmers but could yield good results, e.g. the multiplication and application of soil mycorrhiza	Showcasing of benefits of buying and consuming local, agroecological products to (urban and rural) consumers
Weak or non-existent markets for agroecological products	• Focus on market-building, including public procurement options, possibility of a public certification authority for agroecological products, and engagement with private sector • Support of micro-enterprises in rural areas to produce bio-inputs that are lacking for agroecological production, such as clean native seeds, organic fertilizers, and biological pest- and disease-management products	• Work with farmers and entrepreneurs to develop secondary products (longer lasting, higher priced) that can be made on-farm or in collectives from local agroecological crops • Support of micro-enterprises in rural areas to produce bio-inputs that are lacking for agroecological production, such as clean native seeds, organic fertilizers, and biological pest- and disease-management products	Identification of new marketing outlets (e.g. urban farmers' markets or shops) and innovative arrangements (e.g. direct linking of farmers and consumers) for agroecological products
Lack of focus on issues related to gender	• Mainstreaming of gender-responsive policies into agri-food and other sectors • Explicit focus on systemic ethics (i.e. a systemic understanding of the problems and perspectives	• Stronger integration of gender issues into program planning and implementation • Explicit focus on systemic ethics (i.e. a systemic understanding	• Better taking into account of gender issues in innovation & market development • Explicit focus on systemic ethics (i.e. a systemic understanding

Issue	Suggestions for actions by ...		
	National governments	Civil society	Private sector
	of sustainability, including social justice) and inclusive governance	of the problems and perspectives of sustainability, including social justice) and inclusive governance	of the problems and perspectives of sustainability, including social justice) and inclusive governance

6.4.2 Outlook for further research

Bringing together socio-technical sustainability transitions and agroecological transitions research, the thesis findings open the door to new questions for future research, illustrated in Figure 31. Considering socio-technical transitions theory, five main issues that cut across the chapters, and may be interrelated, arose from the research process and findings of this thesis. First, the stronger integration of biophysical factors, which are inherently important in agriculture and other environmental sectors, is needed to increase socio-technical frameworks' explanatory power. Authors have begun to systematically integrate insights from the literature on socio-ecological research (Loorbach, Frantzeskaki, and Avelino 2017; Scoones et al. 2020) and the application of this to further cases of transitions, particularly ones concerning agri-food transitions, is expected to yield rich results. Recently, debates on the role of nature and non-human agency in transition processes have opened (Contesse et al. 2021), with an agricultural innovation ecosystems approach being suggested to better understand the role of nature as an agent in transitions (Pigford, Hickey, and Klerkx 2018). Second, changes in agri-food systems are inherently cultural processes, yet an engagement with culture is generally absent in the field of sustainability transitions (Meek 2016). Incorporating understandings of the interplays between culture, different worldviews, and sustainability is crucial to ensuring that sustainability transitions processes will be viable in the future and across broad segments of the global population (Ghosh et al. 2021; Preuß et al. 2021). Cultural aspects could be better included in socio-technical frameworks through e.g. the integration of cultural evolutionary insights that investigate the dynamics of value systems, norms, and rules around sustainability (Schlaile et al. 2021). Third, and linked to the previous point, a deeper understanding of what drives individuals to enact sustainability transitions is important to mobilize more people to enact transitions in their daily lives as well as to enact appropriate behavioral public policy supporting transitions (Geels 2020; Kaufman et al. 2021). Related to this are questions of how gender impacts individuals' enactment of transformative behavior in support of sustainability transitions. Here, the social psychology and studies gender literatures can yield insights to support transitions (Upham, Bögel, and Dütschke 2019; Truffer et al. 2022). Fourth, and possibly related to the first two factors, is the integration of landscape factors into socio-technical analyses, particularly in research in Global

South contexts. As this thesis has demonstrated, although the socio-technical frameworks are very useful in clearly identifying entry points for systemic change, their analysis could be sharpened by a more nuanced consideration of the functions, as well as by paying attention to landscape factors that have and continue to shape transition processes (U. E. Hansen et al. 2018; Ramos-Mejía, Franco-Garcia, and Jauregui-Becker 2018; Wieczorek 2018; Edsand 2019; Ghosh et al. 2021). Fifth, the findings point to broader questions of power and justice in transitions. Such questions begin with fundamental issues, such as whom has the power to define basic terms such as sustainability and justice, e.g. which aspects are included, by whom are they desired, and whom do they benefit? They must be addressed in terms of multi-scalar issues, connections, and interactions that take into account spatial, temporal, and administrative scales across sectors (Jenkins, Sovacool, and McCauley 2018; Martiskainen et al. 2021).

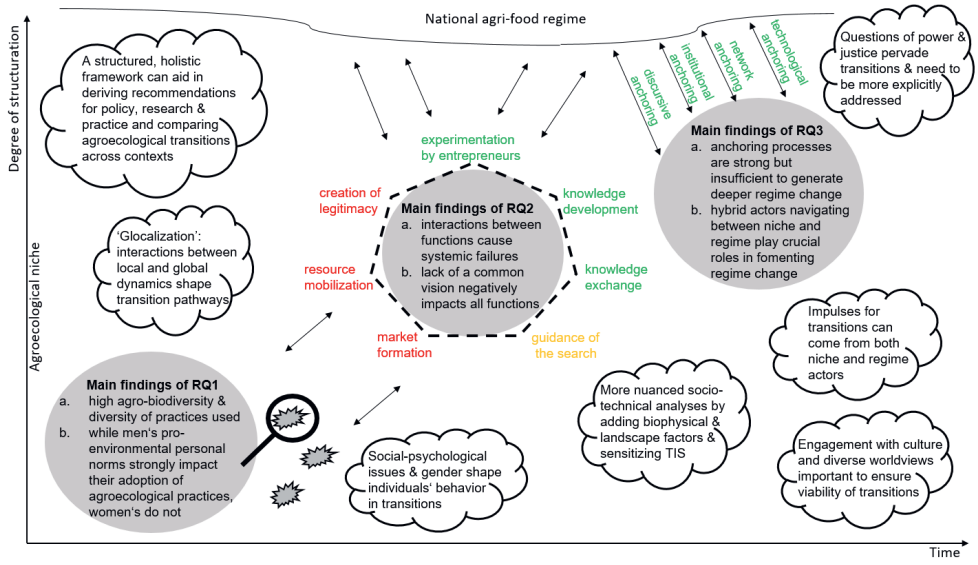

Figure 31: Bridging the agroecological and socio-technical sustainability transitions literatures to better understand agroecological transitions: Central learnings from the research questions and cross-cutting insights from the thesis (Clouds represent cross-cutting insights from the thesis. Colored text illustrates the strength of development of the functions and anchoring processes (red represents poor, yellow is mediocre, green is strong))

Concerning agroecology, the findings of this thesis demonstrate the utility of using a socio-technical systems perspective to explore agroecological transitions. Although agroecology studies that have used socio-technical perspectives have yielded rich insights concerning cross-cutting domains of transformation and key drivers of agroecological transitions, these remain generalized and without providing a structured frame that would make results more easily comparable across contexts (Mier Y Terán Giménez Cacho et al. 2018; Anderson et al. 2021). Understanding the different levels at which changes happen, for example through using a framework like the MLP, can help to better structure

understandings of agroecological transitions and identify specific areas that need change and can be addressed by actors in the agroecological niche. As the failures analysis in section 6.2.3 shows, some systemic failures can be addressed by non-state actors such as civil society, which may be more easily mobilized than national governments. The case study analysis illustrates the utility of analyses based on MLP and TIS for the identification of clear recommendations for policy and practice. With their easily understandable and applicable methods, such analyses are useful tools for identifying entry points that policy makers and practitioners to address and leverage to effect wanted changes towards agroecology. More empirical case studies using the socio-technical frames could help to create a more structured, global understanding of processes of agroecological transitions and how to support these through policy and practice.

Three further issues stand out. First, interactions between local and external dynamics have been integral to the development of agroecology in Nicaragua, and developments in Nicaragua have strongly shaped the science, practice, movement, and political aspects of agroecology at a global level. The importance of transnational linkages for the development of the agroecological niche in Nicaragua has been shown in this thesis and confirms first insights concerning this from sustainability transitions scholars (Binz, Truffer, and Coenen 2014; Gosens, Lu, and Coenen 2015; Wieczorek et al. 2015). Linking to the discussion of glocalization above, further agroecological research can strengthen its analysis of connections between local and global transitions, and the ways in which global agroecological principles are enacted in different geographies. Second, the findings show that both agroecological and transitions research could further be strengthened by a more detailed look at socio-psychological aspects of individuals' behavior in implementing transformative behaviors and practices, and a more nuanced understanding of how individuals' gender informs their enaction of agroecology and transitions (Sarrouy Kay, Lemke, and Pimbert 2016). Third, a nuanced perspective is needed regarding the institutionalization of agroecology into policy. This should be considered from a broad, holistic perspective that considers not just agri-food policy, but related spheres. Accounting for questions of power and representation of stakeholders, and their possible influence-taking on policy, is key (Anderson et al. 2021; Montenegro de Wit et al. 2021). Further, even if policy focuses on just its technological and practical aspects, the potential of agroecology to contribute to climate change mitigation should be utilized.

6.5 Reflections

6.5.1 Reflections on the quality and limitations of the study design

In the following, I reflect on the four quality criteria for case study research, as identified by Yin (2014): construct validity, internal validity, external validity, and reliability.

Construct validity refers to the selection of the most appropriate tools to enable research to produce accurate representations of the object under study (Yin 2014). In this thesis, the construct validity is strengthened through the collection of data from multiple sources and the use of multiple different analytical methods; an iterative research process that included both feedback rounds with stakeholders as well as the critical revisitation of material according to new information; the establishment of a chain of evidence concerning stakeholder input and feedback; and the triangulation of results using different methods, across stakeholder groups and over time.

Internal validity, or the extent of confidence in the analysis and conclusions offered by research, is related to the broader problem of making inferences from data (Yin 2014). While this issue is most applicable to experimental studies that make causal inferences, such as the quantitative survey on which the results in Chapter 3 are based, it also affects case studies that make inferences based on documentary evidence and interviews, such as this dissertation as a whole, Chapter 4, and Chapter 5. The internal validity of the quantitative survey and its outcomes are elaborated upon in Chapter 3. In short, the internal validity of the quantitative survey was strengthened through the following of strict research protocols and the random selection of survey participants from the target population. The internal validity of the qualitatively-based research of Chapters 4 and 5 was enhanced through the use of pattern matching during analysis, a process through which expected patterns are matched to actual observations and data.

The internal validity of Chapters 3, 4, and 5 is limited through several factors, including historical events, which as mentioned prior play a key role in the development of agroecology in Nicaragua. I counteracted this through the triangulation of information from different sources from within and outside of Nicaragua. However, not just historical events, but also the current political landscape - current at the time of the fieldwork, and also current in present times (2023) - limits the internal validity of all parts and of the whole thesis. I sense that many participants in the field study, and actors at events I attended that were peripheral to this study, answered in certain ways that may paint a rosier picture of the agroecological transition than that which one finds in reality. This is true of myself as well. I understand this behavior to stem from a perceived (and since 2018 not just perceived, but realized) sense of threat, emanating from the Nicaraguan government, towards people who do not toe the government line.

The issue of external validity addresses the generalizability of research results to other contexts - and hence, implicitly, also the transferability of findings and learnings. Case studies are particularly useful to generate analytical generalizations (Yin 2014). The use of the socio-technical sustainability transitions framework structures the overall analysis of the thesis and strengthens the external validity of the research, as it allows for the generation of not just generalizable, but also operationalizable results.

The question of research reliability asks to what extent the research can be replicated if the same procedures are followed. Although the reliability of some of the individual data points of this dissertation may not be so high, such as e.g. questionable data from official government sources, the overall

reliability is high due to the application of the socio-technical sustainability transitions framework. The reliability of the results is further strengthened through the iterative research process, and through my self-reflection on my role and limitations as a researcher and individual in this context.

6.5.2 Reflecting on my role as a researcher

Here, I reflect on my role as a researcher during the research process.

My role as a researcher in Nicaragua was shaped by two factors. First, I was a white, foreign, woman. Unconsciously, I may have brought (Eurocentric) researcher biases into all phases of my research, from problem-setting to interpreting the data. Learning much more deeply about Nicaraguan history and culture from a broad variety of people (beyond research participants, also Nicaraguan colleagues, new friends and acquaintances, and my neighbors in Managua) helped me to understand issues from a Nicaraguan perspective and helped shape the findings and conclusions drawn from the research. Second, the research was conducted while I was working for the CIAT, one of fifteen agricultural research center of the CGIAR (formerly Consultative Group for International Agricultural Research). My experience within the CGIAR was fraught with colonialist thought (basic assumption: the Global North inherently has some kind of hegemony over the Global South). For example, an international scientist colleague once told me that in his view, local language skills and a more than superficial understanding of the local context and history are unnecessary to do research. While I have done such research as well in other parts of the world, my experience in Nicaragua taught me the limitations of such an approach. Early on, a different colleague pointed out to me the inherent coloniality involved when international researchers dive into a local context for just a few days, extracting knowledge from local research participants without giving any knowledge back. Throughout my research in Nicaragua, I paid attention to making sure study participants were aware of the value of their knowledge, and strove to also give knowledge back to study participants, e.g. through feedback workshops that fed study results back into the communities they came from. While being a part of CIAT gave me immediate access to many agroecological players, it also shaped how research participants viewed me.

These two factors pervaded all of my professional interactions and I quickly became aware of the power imbalances resulting from this. Because of my foreignness, skin color, and professional affiliation, I was, in many research situations, accorded a power beyond that what I felt I should have as a PhD student who is striving to learn from the local experts. I soon began to directly address this in research situations by making very explicit my role as a learner in this situation, and the research participants' roles as experts from whom I was trying to learn. Both of these factors made me reflect deeply on questions around the coloniality of knowledge and racism.

An issue I struggled with as I was working in the field in Nicaragua was balancing the theoretical and practical aspects of the research. Particularly in the field of agroecology, participatory action research

(PAR) is an important tool to foment change (Holt-Giménez 2002; Guzmán et al. 2012; Putnam et al. 2014; Mendez 2017). Although my research was participatory in some ways (e.g. workshop set-ups), the design of the research itself was not participatory and the research was not action-oriented, in the sense that I did not explicitly involve myself in processes to support agroecology, but rather maintained the conventional researcher-as-observer role. While I tried to avoid reproducing power imbalances, at the end of the day this thesis is highly theoretical and contributes much more to Global North structures (theoretical knowledge on transitions; peer-reviewed journal articles that are part of the educational infrastructure through Wageningen's PhD requirements) than it is useful in the Global South and in the context of Nicaragua. Although I tried, I do not think that this thesis contributed much (yet, hopefully) to the development of agroecology in Nicaragua. However, I think and strongly hope that the relationships and networks created during the research for this thesis will lead to my future participation in supporting agroecology in Nicaragua and elsewhere.

6.6 Final remarks

This concluding section marks the end of the thesis, but not the end of my research journey regarding transitions to more sustainable forms of agri-food production and consumption, particularly in Global South contexts. The background chapter and the three empirical chapters gave a multi-facetted view on the agroecological transition in Nicaragua and demonstrated the added value of using a socio-technical approach to dissect agroecological transitions. They addressed several of the gaps in transitions theories and contribute to discussions surrounding these; the thesis overall contributes an empirical example to further refine transitions theories and methods for use in Global South contexts. As transitions to more sustainable forms of agri-food production and consumption will only grow in importance in face of the ever-deepening climate crisis, both in the Global North and in the Global South, a better understanding of such transitions will help to guide better policy-making to ensure global food security.

Reflecting on the essence of the thesis, two issues stand out. First, Nicaragua's agroecological transitions was induced by, and continues to be shaped by, both grassroots movements and state-led initiatives. This makes it a particularly interesting case to continue watching as regards to the contestation of the national agri-food system and the different ways in which the tensions and syntheses between these two main actor groups will continue to shape the agroecological transition. Second, although supportive policy is necessary to bring transitions to a higher scale of implementation, such policies are insufficient without real political will and/or capacities to implement and enforce them. Although many researchers, practitioners, and activists in the agroecological field consider Nicaragua as an exemplary, iconic case of a successful agroecological transition-in-the-making, the findings of this thesis uncovered many contradictions in this process, particularly at the level of the national government. The findings show that the definition and delineation of agroecology in relationship to other forms of agriculture, be that

organic agriculture or conventional agriculture, is a fraught process contested by multiple stakeholders with different aims and resources. At the beginning of my research process, with my superficial knowledge based mainly on the agroecological literature on Nicaragua, I was optimistic about Nicaragua's agroecological transition, convinced of the national government's support for this and the positive role it had played in scaling agroecology nationwide. By the end of my research process, after talking with many Nicaraguans from all walks of life, this rosy picture had evaporated and I had developed a more critically realist view concerning agroecology in Nicaragua. It seems that some authors writing on agroecology in Nicaragua continue to adhere to an idealized view of the aftermath of the Nicaraguan Revolution that does not seem to take into account the dark sides generated by this process. Yet, scientists, practitioners, and activists have a responsibility to reflect on their personal relationship to their research and to also take into account new facts that may undermine their previously held assumptions. Throughout my research, I have again and again been incredibly impressed by the knowledge, will, and convictions of many people working to enact the agroecological transition on the ground in Nicaragua. Often, these people work in support of agroecology against adverse circumstances in situations of great uncertainty. It is our responsibility as scientists to reflect on our own assumptions and undertake research and publications that truly reflect the complex lived realities of such an agroecological transition, regardless of what public policies lead us to believe.

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