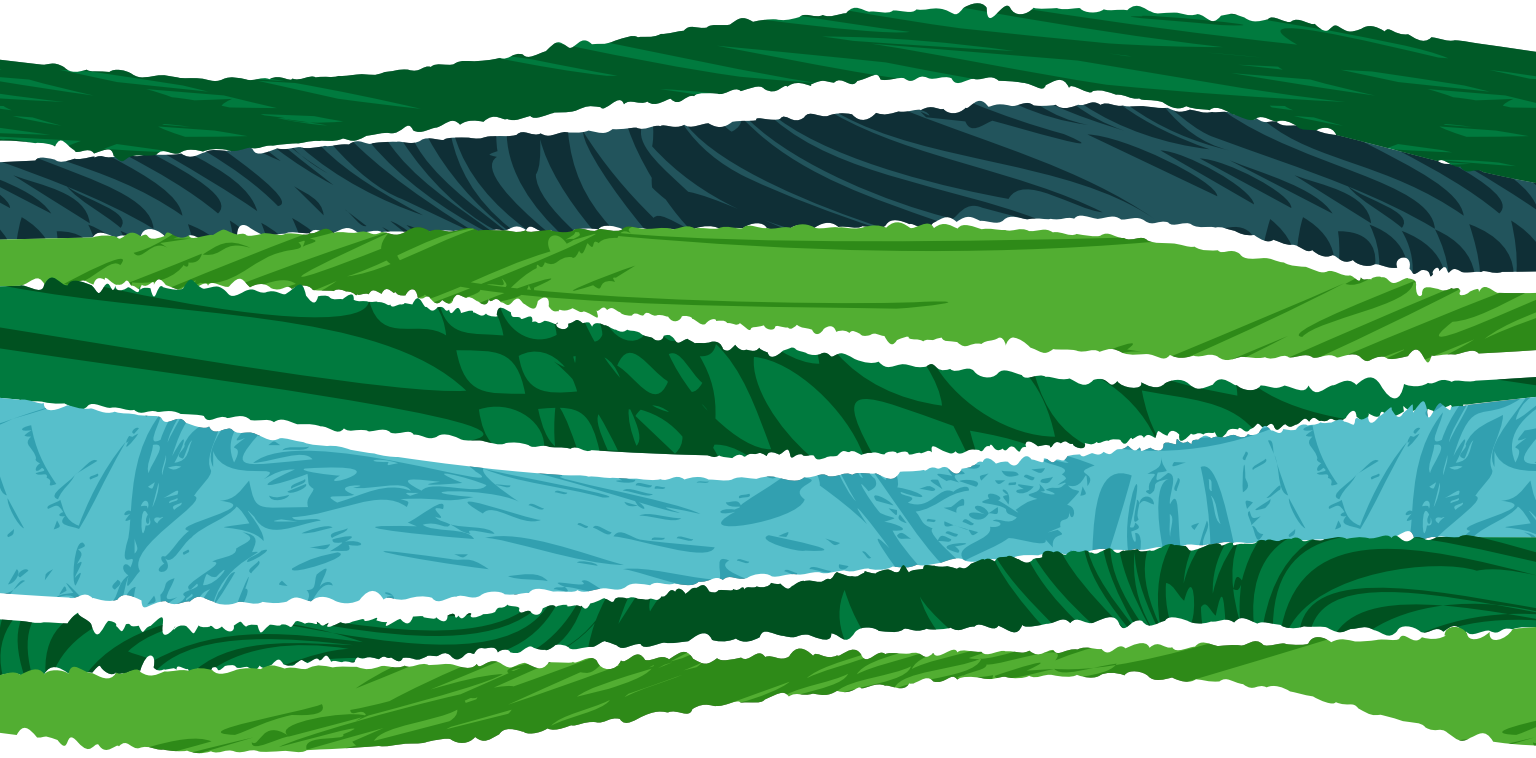
Master in Sustainable Tropical Agriculture:
Transforming Agriculture in Latin America



Zamorano®

Master in Sustainable Tropical Agriculture:
Transforming Agriculture in Latin America

Arie Sanders, Francis Denisse McLean, José Óscar Murillo, and Juan Carlos Rosas

Zamorano®

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This document was prepared by Arie Sanders, Francis Denisse McLean, José Óscar Murillo, and Juan Carlos Rosas. The authors were part of the Master in Sustainable Tropical Agriculture and work for the Graduate Program of the Panamerican Agricultural School, Zamorano.

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THE NIPPON FOUNDATION

In memory of

Jonathan Gustavo Castillo Sánchez

(1996 – 2021)

Contents

Acronyms

AMIR	Association of Renewed Intibucan Women (*Asociación de Mujeres Intibucanas Renovadas*)
CABEI	Central American Bank for Economic Integration
CEASIP	Center of Applied Ecology Simón I. Patiño (*Centro de Ecología Aplicada Simón I. Patiño*)
CIAT	International Center for Tropical Agriculture (*Centro Internacional de Agricultura Tropical*)
CIMMYT	International Maize and Wheat Improvement Center, (*Centro Internacional de Mejoramiento de Maíz y Trigo*)
DNA	Deoxyribonucleic acid
EAFIT	School of Administration, Finances and Technology (*Escuela de Administración, Finanzas y Tecnología*)
EAP	Panamerican Agricultural School (*Escuela Agrícola Panamericana*)
FUSIP	Simón I. Patiño University Foundation (*Fundación Universitaria Simón I. Patiño*)
ICTA	Institute of Agricultural Science and Technology (*Instituto de Ciencias y Tecnologías Agrícolas*)
IFPRI	International Food Policy Research Institute
INCAE	Central American Institute of Business Administration (*Instituto Centroamericano de Administración de Empresas*)
MATS	Master in Sustainable Tropical Agriculture (*Maestría en Agricultura Tropical Sostenible*)
MESCLA	Monitoring and Evaluation Support for Collaborative Learning and Adapting Activity

RNA	Ribonucleic Acid
TNFSA	The Nippon Foundation Scholars Association
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNITEC	Central American Technological University (*Universidad Tecnológica Centroamericana*)
USAID	United States Agency for International Development
UTC La Paz	The Union of Field Workers La Paz (*Unión de Trabajadores del Campo La Paz*)

Foreword

It is an honor for me to present this publication about our Master in Sustainable Tropical Agriculture (*Maestría en Agricultura Tropical Sostenible,* MATS). This graduate program has been an essential part of our mission to transform agrifood education in Latin America, promoting sustainable practices and training leaders of the future with a commitment to innovation and sustainable development.

I would like to express our deepest gratitude to the Nippon Foundation for its generous support and funding over the past six years. Thanks to their invaluable contribution, we have had the privilege of training five classes in the program, benefiting 75 students from 13 countries.

The Nippon Foundation has not only enabled the implementation of the master's program but has also substantially strengthened our scientific research and educational capabilities by equipping our laboratories with state-of-the-art technology on the Zamorano campus.

The impact of the Nippon Foundation has been extremely significant and, undoubtedly, long-lasting. Graduates of the MATS program have advanced knowledge to face current and future challenges, applying it in contexts of socioeconomic and environmental transformation in the agrifood sector, thus contributing to the progress of their communities, society and the planet.

We are deeply grateful for the support of the Nippon Foundation, which has left a legacy of change and social improvement.

Finally, I would like to thank the Zamorano community - academics, students, professionals, administrators and staff - as well as our partners and collaborators for their dedication and effort. Together, we have built a master's program that educates and inspires the next generation of agricultural leaders.

Our vision for 2030 is to be part of a transformation that transcends the traditional boundaries of higher education. In this context, the collaborative work developed with the Nippon Foundation is key to success. Thanks to this union, we are building a brighter and more sustainable future, demonstrating that joint efforts can overcome any challenge and positively transform education and the communities we serve.

We look forward to the future with enthusiasm, confident that the accomplishments and lessons of the MATS program will continue to guide and strengthen our mission to transform lives and positively impact society.

Affectionately yours,

Sergio Rodríquez Royo
President
EAP Zamorano

Preface

The Dean's Office of the Graduate Program at the Panamerican Agricultural School, Zamorano, is pleased to present this report on the impact of the Master in Sustainable Tropical Agriculture (MATS). As Associate Dean, it has been a privilege to lead this program, which has consolidated Zamorano's position as a leader in agricultural education in Latin America and has promoted more sustainable agricultural practices.

The objective of the MATS program was to develop a new generation of agricultural leaders, equipped with the knowledge and skills necessary to transform tropical agriculture in the region.

The goal of the MATS program has been to educate and inspire our students to drive positive change in their communities. Over the years, our graduates have made significant contributions in various sectors, reflecting the training and support received.

I would especially like to thank the Nippon Foundation for their generous support in funding the MATS program. Their commitment to education has been essential to the program's design and implementation and has made our accomplishments possible.

I would also like to thank our faculty, staff and partners, whose support and collaboration have been essential to our success. Special thanks go to the Graduate Program team: Juan Carlos Rosas, research director; José Óscar Murillo, academic coordinator; Francis Denisse McLean, project coordinator; Carolina Machado, administrator; and Danny García, assistant administrator. Their dedication has been key to achieving our objectives.

Additionally, I want to acknowledge Alejandro Osorio from the Office of Institutional Development, who has served as our primary contact with the Nippon Foundation.

As we look ahead, we're enthusiastic about the future of our Graduate's Program. Building on the success of the MATS program, we have introduced new master's degrees. We're also developing additional master's programs and a doctoral program centered on sustainable agriculture and food systems, all based on the solid foundation of the MATS curriculum.

These new offerings will further our mission and broaden Zamorano's impact on agriculture in Latin America. Beyond Zamorano, through MATS' graduates, our university continues to advance the agenda of sustainable agriculture in Latin America, creating positive and lasting change.

Arie Sanders
Associate Dean of the Graduate Program
EAP Zamorano

Summary

In this publication we compile the results of the first six years of implementation of the Master in Sustainable Tropical Agriculture program (*Maestría en Agricultura Tropical Sostenible*, MATS) and present its impact on education and research at Zamorano and in Latin America.

With the implementation of the MATS program, Zamorano achieved two important milestones: entering graduate level education, and explicitly incorporating a focus on sustainability in its educational programs.

The MATS program responds to the need to train professionals capable of addressing the complex problems that characterize the environmental and social challenges of contemporary agriculture.

During its first years of implementation, the program has demonstrated the value of an education that combines theory and practice.

Under an approach that integrates the fields of agronomy, animal husbandry and ecology, scientific knowledge is applied to optimize the interactions between soils, crops, livestock and their surrounding environments. Rather than being treated in isolation, content is addressed in an interconnected manner to provide an integrated view of sustainable agriculture. In this way, students develop a deeper understanding of how agricultural practices can be adjusted and improved to harmonize with agroecological systems. From 2018 to 2024, the MATS program trained 75 students from 13 Latin American countries.

The success of the program is reflected in the achievements of its graduates. Most of them are now working in prestigious companies and research centers throughout Latin America. Many have established their own companies, contributing to local and sustainable economic development. Other graduates have continued their doctoral studies in the United States, demonstrating clearly that the MATS program has successfully supported students' professional growth.

As a result of the research implemented through the MATS program, 51 publications have been produced to date, including 49 articles in peer-reviewed scientific journals and 2 book chapters. Twenty-six percent of the publications have been accepted in highly prestigious journals recognized within the first and second quartile of their discipline.

The research explored multiple possibilities of how to produce more, using fewer resources, and generating less negative impact on the environment and the population. In their research, the students generated evidence on alternatives for sustainable agricultural production adapted to the Latin American context. These works represent empirical examples of how to design and implement solutions to the environmental and socioeco-

nomic challenges of production systems. The MATS program leaves as a legacy Zamorano's Graduate Program. MATS has left a deep imprint on the institution's vision on sustainable agriculture. Building on MATS, new master's degree programs have been established, and a doctoral program focused on sustainable agriculture is being designed.

These new programs seek not only to strengthen research and the development of innovative agricultural practices, but also to train leaders and experts capable of influencing agricultural policies and contributing to the transformation of local, regional and international food systems.

With five graduated classes, the MATS program significantly impacted Zamorano's institutional development. We are grateful to the Nippon Foundation for its critical support in making this program a reality. Looking to the future, we remain committed to supporting Latin American society and generating social innovation in the agricultural sector of our region.

MATS in Numbers

2

Milestones:
1st postgraduate program at Zamorano
1st program focused on sustainable agriculture

2

years full time:
52 credits, 23 courses, 1 internship
Students' dedication:
60% classes, 40% research.

2018-2024

Outcomes:
5 classes, 75 students, 13 countries.

45%

of the 75 students in the MATS program were women.

51

research publications:
49 peer-reviewed articles, 36 primary research articles, 8 literature reviews, 3 policy-oriented notes, 2 opinion articles; 2 book chapters.

26%

of the research publications were accepted in Q1 journals.

60

institutions:
50% first time hosts for Zamorano. 16 countries
43% of students obtained employment or scholarships through their internships

75

full scholarships thanks to the support of the Nippon Foundation.

5

classes have completed their Master in Sustainable Tropical Agriculture program.

Legacy

Established:

1

institutional structure: The Postgraduate Program

1

research conference: Zamorano Investiga

3

new master's programs

Under Design:

3

new master's programs

1

new doctorate program

1. Introduction

Background

In this publication we compile the results of the first six years of implementation of the Master in Sustainable Tropical Agriculture program (Maestría en Agricultura Tropical Sostenible, MATS) and present its impact on education and research at Zamorano and Latin America.

With the implementation of the MATS program, Zamorano achieved two important milestones: entering graduate level education after more than 75 years of offering undergraduate engineering programs, and explicitly incorporating a sustainability focus into its educational programs. These milestones have significantly impacted the evolution of the university during the last decade.

Regarding the first milestone, by establishing MATS, and with it the Graduate Program, Zamorano took the next logical step in its institutional development. Through the MATS program, Zamorano opened a space for an adult student population with more work experience, which requires another teaching dynamic and has greater academic demands.

While in undergraduate engineering programs students take introductory courses, graduate level courses are more specific. Graduate programs aim to turn students into specialists in their field. Students at this level require individualized learning and more support from faculty to develop their skills and achieve their goals.

The student population at the graduate level also has higher demands in terms of research. While engineering students conduct short research projects in their final year, the research component in the MATS program comprises approximately 40% of the students' time.

Research in the MATS program was essential as a learning and assessment tool. To implement their research, students had access to advanced tools and technologies and worked closely with faculty members as their advisors.

With the second milestone, Zamorano aligns itself with the global trend of incorporating a sustainability approach in university educational programs. The United Nations Educational, Scientific and Cultural Organization (UNESCO) declared the period from 2005 to 2014 as the United Nations Decade of Education for Sustainable Development (1).

Driven by this initiative, universities around the world addressed global socioeconomic and environmental challenges in diverse disciplines, including agriculture, engineering, and business. This trend required an integrated approach to educate students in the principles of sustainability and socioeconomic and environmental management (2).

Among agricultural universities, there was a growing emphasis on sustainability to ensure that agricultural practices were socially, eco-

nomically, and environmentally sustainable. Departments of land-grant agricultural universities in the United States introduced courses and programs to teach students about sustainable agriculture, particularly within a context of climate change (3).

The transition from a conventional to a sustainable agriculture approach in these traditional universities with established administrative and academic structures was a gradual process (4). For Zamorano, this process has been no different.

By committing to sustainable agriculture in its first graduate program, Zamorano reflects its vision for the Latin American agrifood sector and its commitment to train those who will lead this sector. With the MATS program, Zamorano established an academic space to experiment with the concepts and practice of sustainable agriculture. By design, research was central to the MATS program to produce results that would foster the sustainability agenda at Zamorano and in Latin America.

The financial support of the Nippon Foundation was instrumental in this process. The Nippon Foundation granted 75 full scholarships for MATS students, allowing the program to be implemented over a period of six years. This funding also strengthened Zamorano's capacity to implement agricultural research by equipping our laboratories with state-of-the-art technology.

Thanks to the support of the Nippon Foundation, Zamorano ventured into graduate education, opening the door to the design and implementation of more educational programs linked to agriculture with a focus on sustainability. In this way, through the MATS program, the Nippon Foundation has advanced its mission of social change and innovation and realized its vision of a society in which all people support each other.

The research conducted through the MATS program had a wide variety of approaches. Students applied innovative methodologies in their research and positively impacted the agricultural industry and society.

The MATS program experience demonstrates the considerable reach that actions of organizations like the Nippon Foundation can have in developing regions, and the value these actions have for the present and future of their people.

Zamorano

The Panamerican Agricultural School, Zamorano, is an American not-for-profit institution committed to training advanced human capital in the agrifood and environmental sectors. The university's main campus is located in the Yeguare Valley, 30 kilometers southeast of Tegucigalpa, the capital of Honduras, and the university has representative offices in the United States, Guatemala, El Salvador, Ecuador and Panama. The university was founded in 1942 by banana magnate Samuel Zemurray.

Zemurray led the development of the banana industry in Honduras and the banana trade to the United States, eventually becoming president of the United Fruit Company, now Chiquita Brands International. Zamorano's first director was Wilson Popenoe, an American botanist and horticulturist, chief agronomist at the United Fruit Company.

From its inception, field work was, and continues to be, an integral part of learning for Zamorano students. Nowadays students spend half of their time working in production, processing and management in the different modules of a 4,000+ hectare campus that operates as a large farm.

This hands-on approach, called "Learning-by-Doing," forms the basis of Zamorano's education. The value of work for Zamorano is clearly reflected in the institution's motto: "Labor Omnia Vincit": Work conquers all.

Zamorano currently offers four BS degrees in Engineering: Agronomy, Agrifood Industry, Agribusiness, and Environment and Development. Thanks to the educational progress achieved through MATS, the university now has three master's degree programs: the Executive Master in Agribusiness, jointly offered with INCAE Business School in Costa Rica, the Master in Agribusiness, jointly offered with EAFIT University in Colombia, and the Master in Coffee and Business, also with EAFIT University.

Zamorano has approximately 1,200 students, including 1,100 undergraduate students living on campus, and roughly 100 students in the master's programs participating in hybrid modalities.

Zamorano's origin has greatly influenced its development as a university. Its culture, which emphasizes production, growth and efficiency as the main objectives, combined with the business nature of the banana sector, resulted in a modernization approach to agriculture, based on external inputs (improved seeds and agrochemicals) and conventional technology (irrigation and mechanization).

Early on, Zamorano assimilated the Green Revolution paradigm, even hosting a visit from the Green Revolution pioneer and Nobel Peace Prize winner, Dr. Norman Borlaug, in the 1960s. Although the production model adopted was successful, new challenges have

emerged that require changing the approach to agriculture (5).

Agricultural systems have made spectacular advances in terms of genetic improvement, agronomy, fertilizers and pesticides. However, many modern practices and technologies have caused soil erosion and degradation, water and air pollution, greenhouse gas emissions, biodiversity losses, and pest and disease resistance (6).

It is not easy, after decades of emphasizing maximizing production, to shift to an approach that must balance a broad set of mitigation and conservation objectives. Nonetheless, facing these challenges, the university recognizes that significant steps in that direction are needed.

Over the past few decades, Zamorano has demonstrated a concerted effort to integrate environmental, social and economic considerations into its academic programs. Zamorano initially introduced a sustainability approach in 1999 during the creation of the 4x4 Program. Under this reform, Zamorano expanded its academic offerings from a single three-year program conferring a degree in Agronomy to four four-year programs offered from four Departments conferring an Engineering degree. One of the established programs, the current Engineering in Environment and Development, focused on natural resource management.

Meanwhile, other engineering programs offered at Zamorano began to integrate sustainability by including classes such as Renewable Energy or Environmental Impact Assessment, and Learning-by-Doing modules such as Climate Change or Soil Conservation. However, a program fully dedicated to sustainable agriculture was a pending goal for the institution.

With the creation of the MATS program, Zamorano's commitment to sustainable agriculture was made concrete. The MATS program was designed to integrate elements from the four Departments under a comprehensive approach to sustainability.

This proposal responds to the need to train professionals capable of addressing the complex problems that characterize the environmental and social challenges of contemporary agriculture. The MATS program positions Zamorano as the leading trainer of such professionals and reflects its institutional commitment to sustainability and innovation. Implementing the MATS program has spearheaded Zamorano's efforts to establish sustainability as our institutional identity, one of the central goals of our Strategic Plan 2030.

2. The MATS program

Conceptual Framework

The MATS program objective was to train professionals with a high level of technical-scientific competencies through a rigorous program based on academic excellence, research, innovation and agricultural linkages to contribute to the sustainable development of the Latin American agricultural sector. To achieve this objective, the MATS program was designed under a conceptual approach of ecological modernization.

Ecological modernization emerged as a reaction to the consequences of the excessive use of inputs, pesticides and irrigation during the Green Revolution. Although the productive intensification of the Green Revolution increased staple crop yields between the 1950s and 1970s, it also negatively affected the health of soils, water and biodiversity (5). In addition, it led to overproduction and declining food prices, which negatively impacted farmers' incomes and consumers' health.

As an alternative, ecological modernization is a sustainability paradigm that focuses on the possibilities that science-based environmental reform processes offer at different scales in the contemporary world (7).

Ecological modernization entered the academic discourse during the 1980s. It initially examined how businesses and institutions integrated environmental considerations into the way they operated through technology (7). Ecological modernization is characterized by an imaginative discourse that conceptualizes environmental problems as opportunities, and potentially interconnected with economic problems (8). The environment and the natural world are recognized as part of society and its cultural, moral and economic systems.

Environmental management is conceived as an opportunity to reduce costs and improve the competitiveness of companies and institutions. Under this paradigm, innovation, modern science and technological advances allow for simultaneous economic growth and environmental conservation.

At the same time, ecological modernization is a reformist rather than a radical paradigm (8). This approach promotes gradual changes and works within existing production models and existing institutional and economic structures.

This alignment allows sustainable practices to be applied on a larger scale, provided that policies, regulations and economic incentives for businesses and consumers are also geared towards sustainability (9).

Ecological modernization theory has been successfully applied to incorporate sustainable practices in multiple sectors, including agriculture. Strategies related to ecological modernization can be distinguished between preventive or anticipatory (ex ante), such as

environmentally friendly technical innovation and structural change; and remedial (ex post), such as environmental compensation and restoration and technical pollution control. In agriculture, the objective of ecological modernization approaches is to improve efficiency in the use of inputs and increase productivity, while minimizing environmental impact, through the application of technologies.

Precision agriculture, for example, involves more efficient use of inputs, including water, fertilizers and pesticides, resulting in less waste and environmental impact. Advances in biotechnology and plant breeding, meanwhile, make it possible to maintain productivity in changing environments and reduce the use of inputs. Ecological modernization also promotes sustainable supply chains that minimize the environmental footprint of agricultural production.

Ecological modernization also encourages various stakeholders, such as policy makers, entrepreneurs and community members, to participate in decision making. In recent decades, ecological modernization approaches have evolved to incorporate social, cultural, spatial, and political considerations (10). They propose a rethinking of market and organizational mechanisms and institutional contexts at the global level, and the consideration of farmer and consumer participation. These new approaches ensure that the solutions proposed from an ecological modernization approach are not only technologically feasible, but also economically and socially viable. As a paradigm, ecological modernization provided MATS students with conceptual tools to incorporate sustainability in agriculture. In this way, students were prepared to drive the industry's transition to more sustainable practices.

By incorporating ecological considerations into economic decision-making, ecological modernization approaches promoted the creation of resilient agricultural systems capable of meeting the growing global demand for food.

Academic Program

The MATS program curriculum comprised 52 credits, offered through 23 courses including a professional internship. Figure 1 presents the academic program designed for MATS based on the conceptual approach described in the previous section. The curriculum is composed of four major components: *agricultural production, socioeconomics and extension, research methods,* and *applied research*.

The *agricultural production* component adopted an integrated approach that combined the fields of agronomy, livestock and ecology. Under this approach, scientific knowledge is applied to optimize the interactions between soils, crops, livestock and their surrounding environments, including water, climate and biodiversity.

The curriculum for this component included six courses: Crop physiology, nutrition and management; Agriculture and climate change; Agroecology; Sustainable animal production systems; Plant protection; and Agricultural biotechnology.

Rather than being treated in isolation, these courses were designed in an interconnected manner to provide an integrated view of sustainable agriculture. Each course contributed to a deeper understanding of how agricultural practices can be adjusted and improved to harmonize with agroecological systems. Through the component's integrative approach, we sought to teach students how ecological principles can be applied to address the challenges of modern agriculture. This approach ranged from reducing environmental impacts and enhancing biodiversity to adapting to climate change and using advanced technologies to develop resilient crops. Through this training, students learned how to develop and implement strategies that not only increase agricultural productivity, but also protect and restore ecological health.

The integration of agronomic, ecological and technological knowledge prepared students to contribute significantly to the sustainability of rural communities by addressing contemporary challenges with innovative, science-based solutions.

In the *socioeconomics* and *extension* component, the MATS program offered six courses: Sustainable agricultural development, Human nutrition in agriculture, Teaching methods in agricultural education, Food safety programs, Natural resource economics and policy, and Agrifood projects evaluation.

These courses examined the relationships between ecological systems and human communities, highlighting how these relationships can foster sustainable agricultural practices and rural development. Overall, the courses fostered in students a critical view on the adaptation of agricultural practices to socioeconomic and institutional changes.

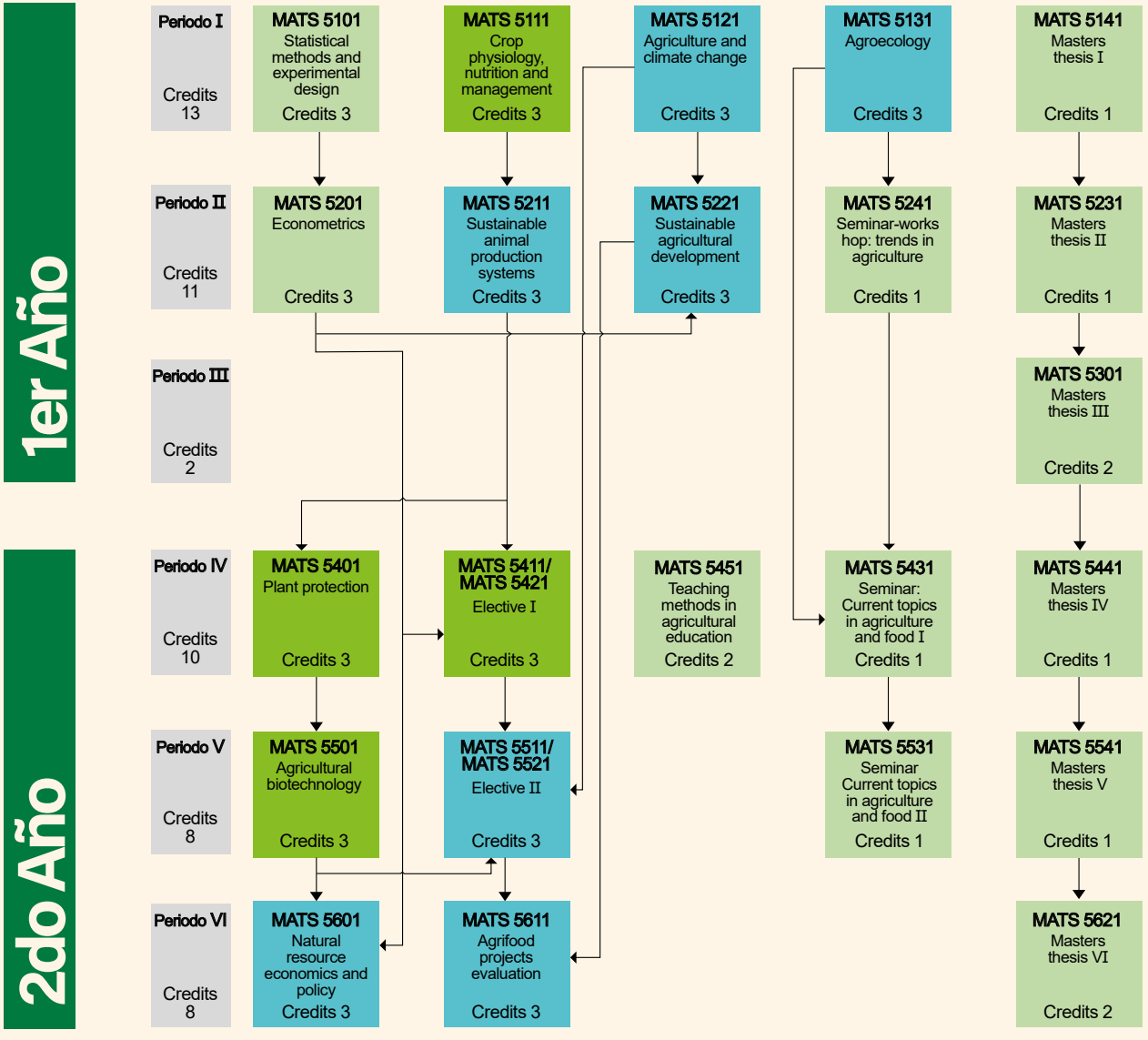
The Sustainable agricultural development course provided an understanding of agriculture and sustainability from a sociological-environmental approach, emphasizing the complex relationships between ecological systems and human communities.

The Human nutrition in agriculture and Food safety program courses were offered as electives. These courses taught students to understand the impact of agricultural practices on public health issues, highlighting the importance of producing nutritious food to promote the well-being and resilience of rural and urban communities.

The Natural resource economics and policy and Agrifood projects evaluation courses allowed students to analyze the economic, policy and project frameworks that influence agricultural sustainability, preparing students to develop and defend policies and projects that balance economic growth with environmental stewardship. Because research is central for the MATS program to achieve its objectives, the courses provide students with the necessary tools to design their research, analyze complex data, and communicate their results with a scientific audience and the public. The *research methods* component offered two courses: Statistical methods and experimental design, and Econometrics.

Finally, in the *applied research* component, students participated every term in a series of courses called "Master's thesis". In these learning spaces, students were trained in methods and tools for research design. In addition, students were offered individualized follow-up to discuss their progress, supplementing the advisory team's guidance. In this way, students were able to address and resolve specific doubts about their thesis projects in a timely manner.

Figure 1: Master in Sustainable Tropical Agriculture MATS program curriculum



Seminars and Academic Activities

Two activities within the MATS curriculum, seminars and field visits, brought into practice the concepts of sustainable agriculture studied in the courses. Seminars involved academic activities related to emerging issues and were also spaces to discuss and design proposals or products aligned with the vision of the MATS program.

For this purpose, the seminars used different pedagogical formats to facilitate learning and discussion of new concepts. Each MATS class had three seminar spaces: Seminar-workshop trends in agriculture, and Seminar on current topics in agriculture and food I and II.

The seminars sought to combine the learning objectives with a sustainability-related need or interest for Zamorano or another organization. For example, among the seminars offered on campus, sstudents designed a sustainable terrace project for the Environment and Development Department, in which they applied *design thinking* concepts to create a space that combined vegetable production, technology and functionality.

In another seminar, the students estimated for the Agribusiness Department the pollution generated by food sale and delivery packaging, and provided training on sustainable packaging to restaurants in four major cities in Honduras. In a seminar that incorporated concepts of circularity, students proposed new products from by-products discarded at Zamorano's agroindustrial plants. Another seminar evaluated the Learning-by-Doing modules based on the concepts of sustainable intensification to determine areas for improvement in terms of sustainability. In an off-campus seminar, students strengthened the sustainable agriculture capacities of volunteer community promoters from two indigenous farmers' organizations: the Association of Renewed Intibucan Women (*Asociación de Mujeres Intibucanas Renovadas*, AMIR) and the Union of Field Workers La Paz (*Unión de Trabajadores del Campo La Paz*, UTC La Paz) in the departments of Intibucá and La Paz, Honduras.

In addition to exploring current issues and trends in sustainable agriculture, the seminars provided students with training in scientific communication, academic writing, use of the library and the use of bibliographic reference management software.

Field visits involved visiting and learning from organizations with advanced vision and extensive experience in sustainable agriculture practices. All classes, except the class of 2022 (due to COVID-19-related restrictions), participated in academic trips to learn about the experience of other institutions in geographic contexts beyond Zamorano. The four field visits organized included:

Agribusiness and sustainability strategies in Guatemala (class of 2020): This trip explored

commodity production around the city of Antigua, Guatemala, in an environmentally diverse area where sugarcane, palm and coffee production converge. During the trip, students explored how large-scale agricultural enterprises implement sustainable agricultural practices in their production systems.

The experience showed that sustainable agriculture is no longer limited to alternative practices in a few niche enterprises, but instead has been adopted by large agribusinesses. Students learned how these agribusinesses have adapted to remain relevant in the international market through certifications and production that considers their social and environmental impact.

Agricultural research and scale-up at the International Maize and Wheat Improvement Center, (Centro Internacional de Mejoramiento de Maíz y Trigo) *CIMMYT, in Mexico* (class of 2021): This trip focused on understanding the operations of the Sustainable Modernization of Traditional Agriculture program, MasAgro, a nationwide extension program implemented by CIMMYT for the Government of Mexico. This program promoted the sustainable intensification of maize, wheat and other cereal production.

During the trip, the students visited different CIMMYT facilities where improved crop varieties, new mechanization technologies, and innovative agricultural practices were being

developed. They also learned how the agricultural extension and collaborative research system based on Innovation Hubs worked.

This trip illustrated how research articulated with a well-designed extension system and the use of adapted technologies can drive the transition from conventional to sustainable agriculture.

Agricultural research and extension at the Institute of Agricultural Science and Technology (Instituto de Ciencia y Tecnología Agrícolas), *ICTA in Guatemala* (class of 2023): This trip focused on providing recommendations for integrating sustainability principles and practices within ICTA's programs and projects. At the time of the trip, as part of its strategic plan ICTA was interested in reforming its operations to integrate sustainability more consistently and transversally into its programs and projects. During this trip, the students visited ICTA's main facilities and three regional centers to learn about their operations and the institution's research and extension work.

The students visited demonstration plots where ICTA implemented genetic improvement, fertilization, irrigation, and soil management programs for maize, beans, and potatoes, the most important food crops for the Guatemalan population. Based on the observations gathered during these visits, students proposed actions and activities to make the operations more sustainable, considering the visited centers' environment, budget and installed capacity.

Regenerative agriculture practices at the Simón I. Patiño University Foundation (Fundación Universitaria Simón I. Patiño, FUSIP) *in Bolivia* (class of 2024): This trip focused on learning how FUSIP was implementing a regenerative agriculture model focused on farming systems at its two farms, Pairumani Estate (*Hacienda Pairumani*) in Cochabamba, and Center of Applied Ecology Simón I. Patiño (*Centro de Ecología Aplicada Simón I. Patiño*, CEASIP) in Santa Cruz.

Pairumani Estate is dedicated to milk production through integrated management that includes forage planting, grazing, composting, milking, and production management, closing the nitrogen cycle. Despite high levels of milk production, the use of external inputs is minimal. CEASIP focuses on the production of a local cattle breed under rotational grazing.

Students visited both centers to learn about their operations. They also organized a series of seminars in educational centers in Santa Cruz to present the progress of their research.

Internships

Professional internships were the last key element in MATS students' training. Internships complemented the theoretical formation students received in the courses and strengthened students' and the institution's professional networks.

During their internship, students applied what they learned in the courses in a professional environment. This allowed them to gain practical experience and make connections with institutions and professionals in the fields in which they would like to work. For the receiving organizations, hosting interns was an opportunity to interact with and assess the capabilities of potential employees.

Among the five classes, MATS students completed professional internships at 60 institutions in 16 countries (Figure 1). Receiving organizations were mainly private companies (40%), universities (31%) and research centers (17%).

Other internships took place at government agencies and non-governmental organizations. Two internships were hosted at projects implemented by Zamorano. Institutions such as Auburn University, University of Tennessee, and Texas Tech University received MATS interns more than once.

Half of the receiving institutions had already received interns from Zamorano's undergraduate programs, while the other receiving institutions represent new connections for Zamorano established through the MATS program. These new connections included agribusinesses from Colombia, Chile, Ecuador, Guatemala, Honduras, Nicaragua and Peru; universities from Ecuador, Panama and Nicaragua; research centers from Bolivia, Colombia, Cuba, Chile, Ecuador, the United States and Mexico; and non-governmental organizations from Colombia, Ecuador, Spain, Honduras and Peru.

The country receiving the largest number of MATS interns was the United States (28%), followed by Honduras (23%), Colombia (11%) and Ecuador (11%). Twenty-eight students (38%) chose to do their internship in their home country to explore the possibilities of obtaining a job upon completion of their masters degree. The remaining students chose to obtain professional experience in an institution outside their home country.

Annex A presents the list of host institutions for MATS students during their internship. Thirty-two students (43%) obtained employment or access to doctoral programs through their internship. The boxes summarize examples of some of the MATS student's internships:

Name: Santiago Loaiza (Ecuador)
Internship: Zamorano, MESCLA-USAID (Honduras)
Year: 2020

During his internship, Santiago worked with the Zamorano Graduate Program faculty on an impact study of the irrigation component of the United States Agency for International Developments (USAID) Feed the Future agricultural assistance programs in the department of Intibucá, Honduras. His work included collecting data to assess and improve local governance of irrigation systems in the region.

The information collected was used for his master's thesis entitled "Water governance and climate action: an experimental perspective from the Honduran Dry Corridor" This research sought to understand and improve water management in the Dry Corridor, a critical area for agriculture and sustainability in Honduras.

Water governance in the Honduran Dry Corridor

Name: Alexandra Espinoza Ayala (Bolivia)
Internship: Ohio State University (United States)
Year: 2021

During her internship in the Department of Horticulture and Agricultural Science (HCS) at The Ohio State University, Alexandra focused on DNA extraction and genetic analysis techniques, including microsatellites (SSRs), for *Taraxacum kok-saghyz* cultivation. Her laboratory experience was complemented by her participation in greenhouse work, which allowed her to improve her skills in both laboratory and field environments.

Through her internship, Alexandra developed a critical perspective on production approaches worldwide, gaining a deeper understanding of sustainability in its multiple dimensions. Her work has strengthened her expertise and broadened her vision of sustainable agricultural practices.

Crop domestication through genomics: *Taraxacum kok-saghyz*

Name: Gissel A. Padilla Sánchez (Honduras)
Internship: EcoHyd (Chile)
Year: 2022

During her internship, Gissel's activities included determining the differences in water consumption between forest plantations and native forests in the riparian areas of three different watersheds in southern Chile (Lebu, Carampangue, and the coastal areas between Lebu and Carampangue). Gissel conducted a comprehensive literature review on water consumption by forest plantations with species such as *Pinus radiata* and *Eucalyptus globulus*, as well as natural forests with species native to Chile.

In addition, Gissel searched and identified available databases to obtain transpiration values globally using satellite products. Her work at EcoHyd allowed her to develop a deeper understanding of the ecological and hydrological impacts of different types of plantations on water consumption.

Water consumption in forestry plantations vs. native forests in southern Chile

Name: Francely Flores (Guatemala)
Internship: World Vegetable Center (Taiwan)
Year: 2023

During her internship, Francely implemented screening protocols to identify candidate genes in tomato and bell pepper varieties susceptible and resistant to southern blight. She performed gene expression analysis using RNA sequencing techniques (RNA-seq) to compare responses of resistant and susceptible plants.

In addition, Francely used bioinformatic tools to identify and prioritize candidate genes associated with southern blight resistance based on transcriptomic data. She validated these genes using molecular biology techniques, such as qPCR, to confirm their role in resistance. She also prepared reports and presentations of the results obtained, including data interpretation and recommendations for future studies.

Evaluation of genes for resistance to southern blight in tomato and bell pepper

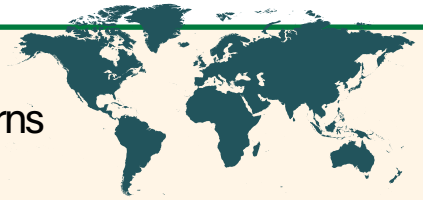
Name: Gerson Montoya (Honduras)
Internship: Hacienda El Empedrado; Valle del Cauca, Colombia.
Year: 2024

During his internship, Gerson worked on applying sustainable animal production practices in dairy farming. Activities focused on evaluating rotational grazing systems to improve forage resource use efficiency and herd diet quality.

Gerson conducted an analysis to improve waste management, including manure composting. In addition, he implemented integrated pest and disease management techniques to reduce the use of chemicals and promoted animal welfare by improving facilities and proper livestock handling. He also worked on training personnel in sustainable practices as well as collecting and analyzing production data to optimize decision making.

Implementation of sustainable animal production practices in tropical dairy farming

Figure 2: Institutions receiving MATS program interns



18 students USA

LSU AgCenter, Alexandria,
Louisiana State University
Penn State University
Michigan State University
Colorado State University
Auburn University
Cornell University
Ohio State University
Texas Tech University
The Ohio State Program
SunGrow Albion, LLC
Universidad de Nebraska
Wisconsin University
Purdue University
University of Florida
University of Tennessee

7 students Colombia

Hacienda El Empedrado
PREMEX
AGROSAVIA
CIAT
C.I UNIBAN S.A
CENICAFE
Pastoral Social de la Arquidiócesis de Florencia

4 students Guatemala

Chiquita - Guatemala
BANAMAR
Secretaría de Agricultura
DISAGRO

2 students Mexico

Centro de Investigaciones Biológicas
DIRECCIÓN DE INOVACIÓN Y DESARROLLO AGROALIMENTARIO DE LA SEDAGRO

2 students Chile

Centro de Cambio Global UC
Plataforma de Investigación en Ecohidrología y Ecohidráulica (EcoHyd)

1 student Panamá

Universidad de Panamá

2 students Perú

Agrovisión Perú
Palmasso

15 students Honduras

Zamorano
AMIR
CIAT
FeedTheChildren
Ideamos S.de R.L.
AGROALPHA
Duwest
SeedChange
DISAGRO/ AGRA
COMSA
Azucarera Tres Valles/ Azucarera Choluteca
FHIA
LEYDE

7 students Ecuador

KOPPERT ECUADOR
CIA LTDA
Visión Mundial
ASOARAPAIMA
Pacchar SA
Inntagriecu Andina S.A.
Universidad Central del Ecuador
Viscarra - Insumos agrícolas
IICA-Ecuador

3 students Nicaragua

Tabacos Plasencia
REPISA Diriamba, Nicaragua.
Universidad Centroamericana

1 student Bolivia

Instituto de Desarrollo Regional

1 student Spain/Perú

Catedra UNESCO Cataluña/ ODM-Perú

1 student Taiwan

World Vegetable Center

1 student Cuba

Instituto de Ciencia Animal

Alumni Network

Upon completion of their participation in the MATS program, graduates become part of the Zamorano alumni network. The Zamorano alumni network forms a close-knit and collaborative community that facilitates the exchange of knowledge, experiences and opportunities among its members. The Zamorano Alumni Outreach Office also provides follow-up to MATS graduates. Through this office, invitations to conferences, events and job offers are shared.

Additionally, the Nippon Foundation launched The Nippon Foundation Scholars Association (TNFSA) platform in 2023. The Association is an exclusive platform that brings together all alumni of Nippon Foundation programs globally, currently including MATS program graduates. The Association aims to connect graduates and offer networking and collaboration opportunities.

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3. Students' Profile

Students' Profile

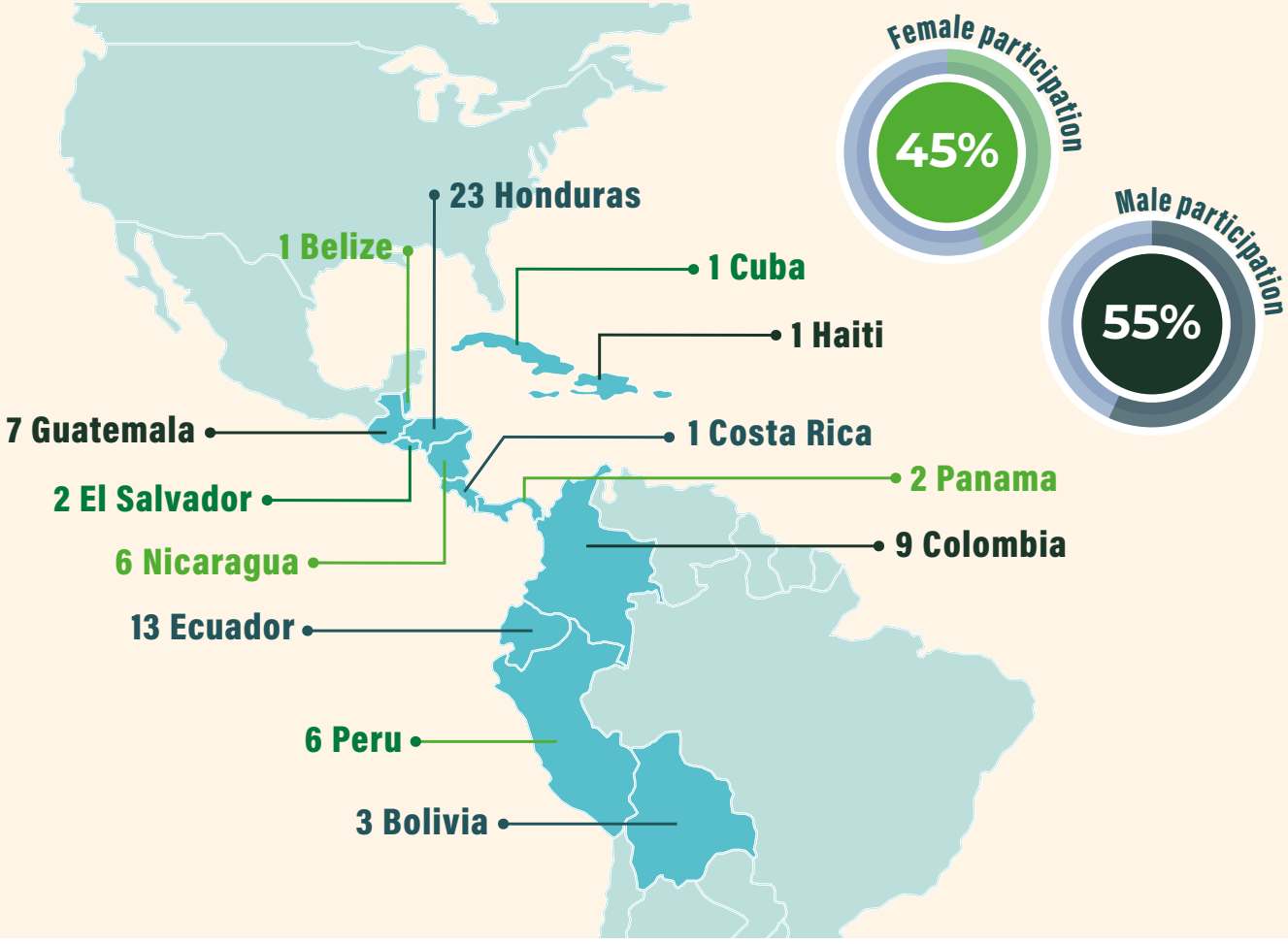
As a Pan-American university, Zamorano has always had an international focus, organizing classes with students from multiple countries and cultures. This vision was transferred to the MATS student classes. In the five classes of the MATS program financed thanks to the support of the Nippon Foundation, we received 75 students from 13 countries (Figure 3).

The country with the highest representation of students was Honduras (31%), followed by Ecuador (13%) and Colombia (12%). Most of the students who entered the program had engineering training at national universities in areas related to agriculture, animal husbandry and natural resources. Twenty-six students (35%) were Zamorano engineering graduates.

The MATS program has actively promoted the participation of women through various activities and approaches. Among them, webinars were conducted with women linked to the agricultural sector to motivate them to join the program. The Graduate Program promotes an institutional culture that is aware of gender biases and celebrates the achievements of female students.

These initiatives have helped women feel empowered and supported in their professional development, thus fostering an inclusive environment that promotes gender equality. Female participation in the different classes ranged from 38% to 60%, reaching 45% in the first five classes of the program.

Figure 3: Composition of the student population of the five classes of the MATS program



4. Research

Thesis Projects

Through their theses or graduation projects, MATS students generated evidence on alternatives for sustainable agricultural production adapted to the Latin American context. These research projects are empirical examples of how to design and implement solutions to the environmental and socioeconomic challenges of production systems (7).

Beyond that, MATS allowed an increase participation and commitment of Latin American reaserchers to solving our own food and agriculture-related problems through science (9). It focused on various aspects of the ecological modernization process, exploring multiple possibilities of how to produce more, using fewer resources, and generating less negative impact on the environment and the population. Annex B presents a full list of the thesis projects.

Productivity gains

A first group of thesis focused on increasing the productivity of agricultural systems. For example, conventional and participatory plant breeding tools, complemented with molecular tools, were used to improve maize (Curruchich, 2023; Gómez, 2021; Macías, 2024) and sorghum (Espinoza, 2021; Igeler, 2023; Solano, 2024) production under the drought conditions typical of the Central American Dry Corridor. The adaptation of local and improved maize varieties to low fertility soils and to the edaphoclimatic conditions of the Honduran maize-growing regions was also studied (Antúnez, 2023; Pierre, 2023). In tomato, the adaptation of new varieties to the climatic conditions of Honduras in open field systems and using macro-tunnels was studied (Flores, 2023).

Other research implemented different techniques to increase crop productivity. The short-term effect of incorporating biochar to improve the chemical characteristics of acid soils for tomato production was evaluated (González, 2024). The soil macrofauna in 11 productive systems on campus and the feasibility of using it as an indicator of soil quality were analyzed (Guardado, 2022).

The organic carbon levels and edaphic microbiota of the productive systems were also characterized as a basis for establishing a regenerative agriculture program at Zamorano (Paiz, 2024). To determine optimal practices for growing jicama, a crop that is not widely grown in Central America, the effects of different planting densities and pruning techniques on yields were evaluated (Molina, 2021). The effect of different planting densities on the vegetative and productive behavior of the rice crop was also analyzed (Villeda, 2022).

In addition, multispectral images were used to predict yields and optimize sugarcane harvesting in Honduras, and machine learning tools were used to evaluate banana yields in Colombia (Gómez, 2024; Huarquila, 2022). A series of theses analyzed how to increase the

productivity of animal production systems. For broiler and layer production, the effect of substituting part of the conventional flours used in feed with alternative ingredients with lower environmental impact, such as rice semolina, discarded beans, wheat bran, coquito meal, annatto, peanut meal, and *Hermetia* (*Hermetia illucens*) larvae meal, was investigated (Atehortua, 2023; Hernandez, 2023). The effects of incorporating synthetic amino acids as substitutes for crude protein, the fungus *Ganoderma Iucidium* as a nutraceutical, and derivatives of a native strain of *Lactobacillus ereuteri* as probiotics were also evaluated (Avain, 2023; Machado, 2020; Melara, 2021).

To improve livestock productivity, integrated crop-livestock systems, key line hydrological designs for pasture management, and regenerative agriculture systems were designed (Cruz, 2022; Holguín, 2020; Villamar, 2023). A standard was proposed to evaluate sustainability in silvopastoral systems based on principles, criteria and indicators (Guacho, 2023).

The sustainability of cattle-producing farms in the Honduran Atlantic Coast was evaluated using RISE 3.0 software (Zelaya, 2024). Animal welfare conditions in Zamorano's dairy and swine units were also evaluated following Welfare Quality® protocols (Martínez, 2022).

Finally, to improve shrimp production, the biostimulant effect of incorporating enzymes and microorganisms in rice bran and soybean meal was investigated (Caballero, 2021).

Input reduction

A second group of theses focused on reducing the use of inputs in agricultural prodution. To reduce pesticide use, one set of theses explored alternatives based on the principles of biological control and integrated pest management (IPM). These included the use of *Trichoderma* to control *Fusarium solani* in tomato (Baca, 2020); the use of *Cordyceps fumosorosea* to control *Bemisia tabaci* also in tomato (Vera 2021); the use of the fungi *Paecilomyces lilacinus*, *Pochonia chlamydosporia* and *Trichoderma harzianum* to control the nematodes *Meloidogyne* spp. and *Pratylenchus* spp in watermelon and banana (Rosero, 2024); the use of *Amblyseius swirskii* to control mites, whiteflies and thrips in sweet chili (Villamarín, 2022); and the use of *Neoseiulus cucumeris* to control mites, aphids, whiteflies, thrips and psyllids in several crops (Lopez, 2024). In addition, the introduction of lambs in lemon plantations for biological control of weeds was explored (Becerra, 2023).

Other approaches explored to reduce pesticide use included the use of mineral fungicides in cocoa cultivation (Ramos, 2020). Genetic resistance to the tar spot complex in maize and Huanglongbing disease in citrus was also explored using multispectral images collected with remote sensors installed on drones (Jiménez, 2021; Padilla, 2022; Puerto, 2020).

To reduce herbicide applications, the use of maize and sorghum residues as cover crops in maize production, and the use of intercropped legumes as live cover crops in sugarcane production were explored (Landa, 2020; Ricaurte, 2023; Tello, 2021).

To reduce fertilizer applications, the use of organic acids to enhance nutrient absorption and avoid losses due to low availability and leaching in rice (D' Vicente, 2022); the use of biofertilizers based on the endemic bacteria *Stenotrophomonas spp.* and *Pseudomonas spp.* in maize (Gamez, 2024); the use of *Azospirillum spp.* as a biofertilizer in maize, sorghum and rice (Montoya, 2024); and the application of the biostimulant Nutrisorb-L® in sugarcane (Landa, 2020) were explored. Precision agriculture practices were also explored to optimize input use in bean and sorghum seed production (Rosas, 2021).

To improve water use efficiency in Zamorano, the effect of clay content on soil moisture retention was investigated, and future scenarios of water availability for productive zones were projected (Gonzalez de Leon, 2022; Madriz, 2022). Off campus, socioeconomic and cultural factors that influence Honduran farmers to adopt climate-adapted sustainable agriculture practices were studied (Tax, 2021). Finally, among the possibilities to reduce soil dependency, protocols were designed for green fodder hydroponic production (Redrovan, 2022) and lettuce aquaponic production (Osorto, 2021; Redrovan, 2022).

Negative impact reduction

A third group of theses focused on reducing the impact of agricultural production. Research aimed at reducing pollution evaluated the effect of nutraceutical diets on litter management and nitrogen and potassium losses in broiler production (Gutierrez, 2020). Greenhouse gas emissions from dairy production systems in Honduras and the potential mitigating effect of a series of management practices were also modeled (Marín, 2020). In coffee, as a lower environmental impact alternative to conventional fermentation and washing, the effect of soaking coffee in organic acids after mechanical demucilaging was explored (Retes, 2021).

Other research targeted reducing food waste. In bean lines, the presence of resistance to weevil damage under on-farm storage conditions was examined, as well as the genetic basis of this resistance (Lemus, 2022; Palomino, 2024). In raw foods of animal origin, the application of the technology known as "functional ice" (FICE) to reduce deterioration and maintain quality during storage and transport was studied (Wú, 2020).

In terms of reducing the negative impact of food consumption on people's health, the presence of aflatoxins and fumonisins in maize dough and tortillas, and the levels of dietary exposure to which consumers are expo-

sed, were quantified (Cabrera, 2020). Among first-year Zamorano students, the dietary behavior and acceptance and adherence to a healthy and sustainable diet were examined (Enriquez, 2021). The nutritional status of school students in Honduras was also evaluated, as well as their barriers to access a healthy diet (Jarquín, 2024).

Social, cultural, political and organizational aspects

A final group of theses focused on the social, cultural, political and organizational aspects related to sustainable agriculture. Regarding social and cultural aspects, research explored topics such as the perceptions and preferences of Honduran and Colombian coffee consumers and their willingness to pay for sustainability attributes (Achicanoy, 2024; Mamani 2022); perceptions on sustainable agriculture among Zamorano graduates (Chuquillanqui, 2023); and the perceptions of Honduran and Peruvian coffee farmers on the presence and conservation of wild mammals in their plantations (Huamaní, 2023).

In Honduras, the relationship between life satisfaction levels of rural youth and their intention to migrate was investigated (Meléndez, 2024). The social constructions surrounding the use of pesticides among potato producers were also analyzed; and the agrobiodiversity and management practices of home gardens in the Dry Corridor were characterized (Benavides, 2023; Vásquez, 2021). Research with a gender perspective addressed the role of rural women's empowerment in child nutrition; the role of women in sustainable coffee production; and the management of coffee rust disease (Correa, 2024; Jerez, 2022; Navarro, 2023).

Regarding political and organizational aspects, Central American public policies aimed at promoting sustainable tropical agriculture from an ecological modernization perspective were analyzed (Del Valle, 2021). In the Honduran Dry Corridor, water governance processes were examined from a collective action perspective (Loaiza, 2020). In Ecuador, the impact of productive actions linked to oil palm production on the socio-territorial relations of an indigenous community was analyzed (Tipán, 2020). Finally, in Honduras, the role of formalized social networks as mechanisms to confront the COVID-19 pandemic and as a mechanism to empower rural indigenous women was analyzed (Reiche, 2020; Ullaguari, 2022).

Outstanding Work

In this section, we highlight some of the thesis projects MATS students completed, to illustrate the different approaches students applied to address issues in sustainable agriculture, and the scientific and social implications of their findings.

Andrea Reiche, **class of 2020**, documented in her research how Lenca women farmers organized through the Association of Renewed Intibucan Women (*Asociación de Mujeres Intibucanas Renovadas*, AMIR) in Intibucá, Honduras, implemented individual and collective strategies to cope with conditions of inequality, marginalization and poverty. To explore AMIR members' experiences, Andrea applied qualitative research techniques such as participant observation, semi-structured interviews and the participatory action research methodology "photovoice".

In "photovoice", participants captured photographs of their own daily lives. These photographs served as a basis for participants to discuss with the researcher their individual strengths and problems and those of their community. Andrea's findings showed how grass roots organizations such as AMIR that propose problems and solutions based on women's own experience improve social inclusion, natural and economic resource management, and the sustainability of agrifood systems. This knowledge contributes to improving the effectiveness of other programs and projects targeting rural women.

To identify maize varieties with tolerance to drought stress, **Marvin Gómez, class of 2021**, characterized the phenotype of 30 open-pollinated local and improved varieties stored at the Zamorano Germplasm Bank. The samples came from the maize-growing regions of El Salvador and Honduras. In the trial, the samples were exposed to three conditions to simulate the drought stress that plants might face in the field: In the no stress condition, plants received irrigation until they reached physiological maturity; in the moderate stress condition, irrigation was interrupted during the blister stage; and in the severe stress condition, irrigation was interrupted around flowering time.

Findings showed that Capulin, Olotillo, Indio, Planta Baja and Olotillo Mejorado varieties had good yield potential and stability through the evaluated conditions. These correspond to white maize varieties collected in the departments of Choluteca, Santa Bárbara and Yoro in Honduras. Marvin also identified that the secondary traits of number of ears per plant, ear appearance, 100-seed weight, and number of days from planting to leaf senescence were correlated with crop performance under drought stress. These findings will be used in future breeding efforts to develop drought stress tolerant germplasm.

Wendy Villamarín, **class of 2022**, explored the optimal field management conditions to increase the effectiveness of the predatory

mite *Amblyseius swirskii* for the control of thrips, whiteflies and phytophagous mites in sweet pepper production. The research compared four storage temperatures (4°C, 10°C, 25°C and 33°C), two packages (jar and bag), and four release methods (manual, mechanical blower, and the slow-release methods "sachet" and "Zamobox"). The effect of introducing artemia salina and *Carpoglyphus lactis* as supplementary food on the population dynamics and control effectiveness of *A. swirskii* on thrips was also studied. The results showed that the ideal condition for storing *A. swirskii* is 25°C - 33°C in a jar for adult individuals, and 4°C in a bag for eggs. All release methods allowed dispersal and persistence of *A. swirskii* for up to three months in the crop. The joint introduction of

supplementary food increased the number of mobile individuals of the predator per hectare by 30. These findings contribute to the effective control of thrips, a polyphagous and invasive pest important for a variety of vegetable and ornamental crops worldwide.

Mayra Atehortua, **class of 2023**, investigated the possibilities of using *Hermetia* larvae meal (*Hermetia illucens* (L.)) as an alternative ingredient in broiler chicken diets. *Hermetia* larvae are used as feed for different animals - from fish to humans - because of their high nutritional levels, palatability, and high protein quality. Their production is sustainable because they can be fed on organic animal and plant waste, including pig, poultry and cattle manure. In her research, Mayra studied the effect of including *Hermetia* larvae meal in three percentages (10, 15 and 20%) in

broilers diet. She found that including larvae meal did not cause morbidity and mortality, nor did it change live weight, relative edible portion weight, immune performance, litter characteristics, or chemical composition of the breast in broilers. Including 15% of *Hermetia* larvae meal in the diet improved feed conversion by 30%, while including 20% reduced the presence of pathogenic bacteria.

These findings suggest that *Hermetia* larvae meal is a viable feed alternative in the poultry industry and can be used as a partial replacement for soybean meal, synthetic amino acids, vegetable oil and phosphate in proportions up to 20%.

Ana María Gómez, **class of 2024**, evaluated machine learning models to predict banana yields in plantations in Urabá, an important banana growing sub-region in Colombia. Information used to build the models came from multiple sources, including farmer records, weather stations, marketing companies, agricultural technology service companies, and satellite databases.

The research evaluated the predictive power of four algorithms using RapidMiner software. According to the results, the variables that best predicted yield were the average number of bunches harvested per hectare per week, the number of boxes per bunch, the average weight of the bunches, the amount of phosphorus and sulfur applied per hectare, the nitrogen content in the stem, and rainfall. The algorithm known as a support vector machine demonstrated the best predictive power.

The findings demonstrate that machine learning is a viable digital alternative for predicting banana yield, explaining possible yield effects, and facilitating management decisions based on historical data.

Zamorano Investiga

As part of the MATS program, the Graduate Program organized an annual conference on research at Zamorano called *Zamorano Investiga*. The objective of Zamorano Investiga was to project the research implemented at Zamorano at the engineering and graduate level. At the same time, the event offered students a platform to interact with faculty and guest researchers.

During the event, students presented their research projects at different stages, from proposals and preliminary results to results and article drafts. Presentations encouraged students to develop public speaking and scientific communication skills. They also provided students with feedback on their research approach, methodologies and results from colleagues from different years and

backgrounds and from other researchers. The best research papers presented as oral presentations or posters received an award. These awards motivated students to present their work through high quality communication products. In 2021, *Ceiba*, Zamorano's scientific journal, published a special edition with the award-winning research from *Zamorano Investiga*.

The conference also featured presentations by Zamorano faculty about the progress of their research, and keynote talks by guest researchers. These talks encouraged students to broaden their perspectives on current topics in sustainable agriculture, presenting new ideas on research approaches and methodologies.

As guests at *Zamorano Investiga* we have hosted researchers from the International Food Policy Research Institute (IFPRI) in the United States, the International Center for Tropical Agriculture (*Centro internacional de Agricultura Tropical,* CIAT) in Colombia, the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, and a leading institution in organic regenerative agriculture, the Rodale Institute in the United States.

We have also hosted guest academics from other universities such as the National Autonomous University of Honduras (*Universidad Nacional Autónoma de Honduras*, UNAH), EAFIT University in Colombia, Ohio State University in the United States, and Loyola University and the University of Cordoba in Spain. Among guests from the private sector, we have hosted representatives from the irrigation company for sustainable agriculture Netafim, in Honduras, and the floriculture company El Trigal, in Colombia. As a guest from the cooperation sector, we have received representatives from the Central American Bank for Economic Integration (CABEI).

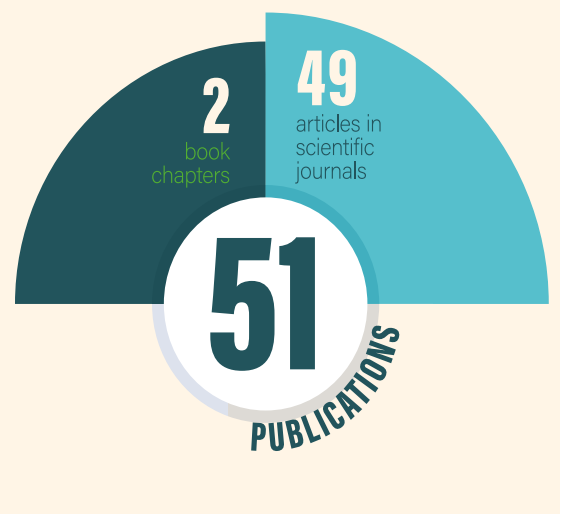
Thanks to the positive reception *Zamorano Investiga* has received, the conference has been institutionalized and it is organized annually by the Graduate Program, the different Departments of Zamorano and the Academic Dean's Office.

Publications

To date, 51 publications have been produced from the research implemented through the MATS program, including 49 articles in peer-reviewed scientific journals and 2 book chapters. The peer-reviewed articles included, in addition to primary research articles, 8 literature reviews, 3 policy-oriented notes and 2 opinion articles.

Twenty-six percent of the publications have been accepted in high prestige journals recognized within the first and second quartile (Q1 and Q2) within their discipline. High impact journals include *Animal Physiology*, *Critical Reviews In Food Science and Nutrition*, *Heliyon*, *Plants*, and *Sustainability*. While most of the publications (53%) were written in English with the intention of reaching a wider academic audience, 47% of the publications were written in Spanish.

The representation of MATS articles in Central American scientific journals was also notable. Twelve articles (24%) were published in *Ceiba*, Zamorano's scientific journal, while seven articles (14%) were published in *Innovare, Revista de Ciencia y Tecnología*, the science and technology journal from the Central American Technological University (*Universidad Tecnológica Centroamericana*, UNITEC) in Honduras. This reflects the commitment of MATS students and faculty to Latin American,



and the intention to produce research by and for the region, proposing solutions to local problems.

In addition to 31 articles published to date on the students' thesis projects, ten publications have been produced from the students' collaboration as research assistants to thesis advisors or their internship supervisors. These publications address agronomic topics such as genetic diversity in beans (Gómez et al., 2021a) and tomato (Flores et al., 2024); and nutrition topics such as the nutritional status of lactating mothers (Hernandez-Santana et al., 2021), the social and cultural influences on food decisions (Enriquez et al., 2021), the nutritional consequences of the reduction of Andean crops (Gaucho et al., 2023a), and the nutritional quality of processed food (Hernandez Santana et al., 2020); They also address socioeconomic topics such as the role of farmers in the decentralization of breeding programs (Gómez et al., 2021b), the effect of the COVID-19 pandemic on women (Fromm et al., 2022), and farmers' perceptions and adaptation strategies to climate change (Landaverde et al., 2022).

Additionally, nine articles have been published as a product of the Human nutrition and agriculture course. In these articles students reviewed the literature on food self-sufficiency (Enriquez, 2020), agricultural diversification (Vasquez Reyes et al., 2020), Ecuador's Zero Hunger program (Enriquez et al., 2020), and food waste (Avain et al., 2022), and the impact of these issues on food and nutrition security in communities. MATS students also produced opinion pieces on the effect of social networks on nutrition (Mamani Escobar et al., 2021), and food and nutrition security in the Honduran educational system (Igeler Cáceres and Bernal, 2023); and policy briefs on backyard poultry farming (Becerra A et al., 2023), the transition of the Honduran food system toward sustainability (Gaucho et al., 2023b); and the contribution of food agroindustry to nutrition (Hernández et al., 2023). Annex C presents a full list of these publications.

5. Reflections: The MATS Legacy

The MATS program legacy

The graduation of the MATS program fifth class is a moment to reflect on the traveled path, the achievements made, and the legacy established. Between 2018 and 2024, the MATS program trained 75 students from 13 Latin American countries. The success of the program is reflected in the achievements of its graduates. Most of them are now working in prestigious companies and research centers throughout Latin America.

Many have established their own companies, contributing to local and sustainable economic development. Other graduates have continued their doctoral studies in the United States, concretely demonstrating that the MATS program has successfully supported students' professional growth.

Over the years, the MATS program has demonstrated the value of a comprehensive

education that combines theory and practice. The MATS approach has produced a group of professionals prepared to address the challenges facing agriculture in Latin America. Graduates of the program are now applying their skills and knowledge in diverse sectors, driving sustainable initiatives and innovations in their respective communities.

Beyond its graduates, the MATS program has built a culture of critical thinking in faculty and students at all levels at Zamorano. The MATS program's training, research and outreach activities promoted constructive analysis and debate on best practices and policies for sustainable and resilient agriculture. This culture has enriched the entire community, fostering a vibrant and dynamic academic environment at Zamorano.

The MATS program also leaves as a legacy Zamorano's Graduate Program. The MATS program has left a deep imprint on the institution's vision on sustainable agriculture. The sustainability focus of MATS, as Zamorano's first graduate program, ensures that sustainability will be the foundation of our future educational efforts. MATS principles and achievements will continue to inspire initiatives to expand graduate offerings at Zamorano. Building on the MATS experience, new master's degree programs have been established, and a doctoral program focused on sustainable agriculture is being designed. These new programs not only seek to strengthen research and the development of innovative agricultural practices, but also to train leaders and experts capable of influencing agricultural policies and contributing to the transformation of local, regional and international food systems.

The graduation of the MATS program's fifth class completes a significant chapter in Zamorano's institutional development. We thank the Nippon Foundation for its fundamental support in making the MATS program a reality. Looking to the future, we remain committed to supporting Latin American society and generating social innovation in the agricultural sector of our region.

6. Annexes

Annex A

List of Host Institutions for Internships

Cohort	Student's name	Country of origin	Country of internship	Institution
2020	Andrea Reiche	Guatemala	Honduras	Asociación de Mujeres Intibucanas Renovadas (AMIR)
	Bet Wú	Honduras	United States	Auburn University
	Blanca Ramos	Honduras	Honduras	Fundación Hondureña para la Investigación Agrícola (FHIA)
	Carlos Puerto	Honduras	United States	Purdue University
	Dikson Marin	Colombia	Colombia	PREMEX
	Emil Vásquez	Honduras	Colombia	Centro Nacional de Investigaciones de Café (CENICAFÉ)
	Jeimy Cabrera	Honduras	United States	Nebraska University
	Jorge Caballero	Panama	Mexico	Centro de Investigaciones Biológicas
	José Landa	Honduras	Honduras	Azucarera Tres Valles/ Azucarera Choluteca
	Maria Mamani	Bolivia	Bolivia	Instituto de Desarrollo Regional
	Melany Gutierrez	Bolivia	Colombia	Corporación Colombiana de Investigación Agropecuaria (AGRO SAVIA)
	Miguel Tipán	Ecuador	Ecuador	Asociación de Producción Acuícola Arapaima Sucumbíos Paiche Arapaima-ARAPAIMA
	Óscar Machado	Honduras	United States	Auburn University
	Samuel Baca	Nicaragua	Nicaragua	Universidad Centroamericana
	Santiago Loaiza	Ecuador	Ecuador	Universidad Central del Ecuador

Cohort	Student's name	Country of origin	Country of internship	Institution
2021	Alexandra Espinoza	Bolivia	United States	Ohio State University
	Andres Tello	Peru	Mexico	Dirección de Innovación y Desarrollo Agroalimentario de la Secretaría de Agricultura y Desarrollo Rural (SEDAGRO)
	Danna Vera	Ecuador	Ecuador	Instituto Interamericano de Cooperación para la Agricultura-Ecuador -(IICA)
	Diego Rosas	Guatemala	Guatemala	DISAGRO
	Erick Osorto	Honduras	Honduras	Agencia Adventista de Desarrollo y Recursos Asistenciales (ADRA)
	Fidel Jimenez	Panama	Panama	Universidad de Panamá
	Jean Pierre Enriquez	Ecuador	United States	University of Tennessee
	Marco Molina	Nicaragua	Nicaragua	REPISA Diriamba, Nicaragua.
	Marvin Gomez	Honduras	Honduras	SeedChange (Organización Canadiense)
	Rodrigo Retes	Honduras	Honduras	Café Orgánico Marcala S.A. (COMSA)
	Verónica Tax	Guatemala	Guatemala	Secretaría de Agricultura
2022	Allen Jimena Martinez	Honduras	Honduras	EAP-Zamorano
	Alondra Cruz	Honduras	United States	Texas Tech University
	Aquileo Gonzalez	Nicaragua	Colombia	Centro Internacional de Agricultura Tropical (CIAT)
	Brenda Mamani	Bolivia	United States	Texas Tech University

Cohort	Student's name	Country of origin	Country of internship	Institution
2022	Catheryne Beatriz Jerez Sarceno	Guatemala	United States	University of Tennessee
	Daniela Redrovan	Ecuador	United States	Texas Tech University
	Delmer Lemus	Honduras	Honduras	AGROALPHA
	Emanuel Villeda Rivera	Honduras	Guatemala	BANAMAR
	Gissel Alejandra Padilla Sánchez	Honduras	Chile	Plataforma de Investigación en Ecohidrología y Ecohidráulica (EcoHyd)
	Juan Xavier Ullaguari	Ecuador	United States	Ohio State University
	Narriman Madriz	Nicaragua	Chile	Centro de Cambio Global
	Victor D´Vicente	Honduras	Honduras	Duwest
	Walter Guardado	El Salvador	Chile	Centro de Cambio Global
	Wendy Villamarin	Colombia	United States	University of Florida
	William Andres Huarquila Henriquez	Ecuador	Ecuador	Inntagriecu Andina S.A.
2023	Arazay Avaín	Cuba	Cuba	Instituto de Ciencia Animal
	Denís Huamani	Peru	Spain	Catedra UNESCO Cataluña
	Elias Hernandez	Nicaragua	United States	Auburn University
	Emma Navarro	Honduras	United States	Tennessee University
	Francely Flores	Guatemala	Taiwan	World Vegetable Center
	Francisco Villamar	Ecuador	Nicaragua	Tabacos Plasencia

Cohort	Student's name	Country of origin	Country of internship	Institution
2023	Fritzner Pierre	Haití	United States	Penn State University
	Gesler Antunez	Honduras	United States	Michigan State University
	Jaqueline Chuquillanqui	Peru	Honduras	Ideamos S.de R.L.
	Jessika Becerra	Colombia	United States	Colorado State University
	Lourdes Guacho	Ecuador	Ecuador	Visión Mundial
	Luis Ricaurte	Ecuador	United States	Auburn University
	Mayra Atehortua	Colombia	United States	Auburn University
	Santiago Benavides	Colombia	Colombia	Pastoral Social de la Arquidiócesis de Florencia
	Wesly Curruchich	Guatemala	United States	Wisconsin University
	William Igeler	Honduras	Honduras	Alliance of Biodiversity International y CIAT bajo el auspicio del CGIAR.
2024	Ana María Gómez	Colombia	Colombia	Uniban S.A
	Debby Melendez	Costa Rica	United States	Cornell University
	Edwin Palomino Velasque	Peru	Peru	Agrovisión Perú
	Elsa Gabriela Zelaya	Honduras	Honduras	LEYDE S.A.
	Felicano Valderama Solano	Peru	Peru	Palmasso
	Gabriel Gonzalez	Ecuador	Ecuador	Pacchar SA

Cohort	Student's name	Country of origin	Country of internship	Institution
2024	Gabriel Gonzalez	Ecuador	United States	The Ohio State Program SunGrow Albion, LLC
	Gerson Fabricio Montoya	Honduras	Colombia	Hacienda El Empedrado
	Jessika Rosero	Colombia	Ecuador	Koppert CIA LTDA
	Leroy Randolph López	Belize	United States	Louisiana State University
	Luis David Jarquín	Honduras	Honduras	Feed the Children
	Luisa Correa	Colombia	Honduras	Proyecto Investigando Sistemas Agroalimentarios 8ISA)
	Marvin Gamez	Nicaragua	Honduras	Lab de Control Biológico- Zamorano
	Noe Humberto Paiz	Guatemala	Guatemala	Chiquita
	Pedro Macias	Ecuador	Ecuador	Viscarra - Insumos agrícolas
	Viviana Achicanoy	Colombia	Honduras	Alliance Biodiversity- CIAT

Annex B

List of Thesis Projects

Achicanoy, V., 2024. *Preferencias de sostenibilidad de los consumidores colombianos de café:* EAP Zamorano. Honduras. https://hdl.handle.net/11036/7774. [Asesores: Sandoval, Luis; Morales, Sarahí].

Antúnez, G., 2023. *Validación participativa de la adaptación de variedades de maíz a la variabilidad edafoclimática en Honduras:* EAP Zamorano. Honduras. https://hdl.handle.net/11036/7502. [Asesores: Colbert, Raphael; Rodríguez, Iveth; McLean, Francis].

Atehortua, M., 2023. *Valor nutritivo de la harina de larva de Hermetia (Hermetia illucens (L.)) y su empleo en la alimentación de pollos de engorde*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7479.2. [Asesores: Martinez, Yordan; Orozco, Jesús].

Avain, A., 2023. *Efecto nutracéutico del hongo Ganoderma lucidum en los indicadores biolgicos de pollos de engorde*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7480. [Asesores: Martinez, Yordan].

Baca, S., 2020. *Caracterización molecular de Trichoderma spp. y su potencial en el control de Fusarium solani y como promotor de crecimiento en tomate*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6720. [Asesores: Trabanino, Rogelio; Avellaneda, Carolina; Jiménez, Oswalt].

Becerra, J., 2023. C*ontrol biológico de arvenses utilizando corderos en una plantación de limón en el Valle de Yeguare, Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7513. [Asesores: Matamoros, Isidro; Trejo, Celia O; Avellaneda, Carolina].

Benavides, S., 2023. *Construcción social alrededor del uso de plaguicidas: Un estudio en la producción de papa en Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7506. [Asesores: Sanders, Arie; McLean, Francis].

Bendeck, V., 2024. *Empoderamiento de la mujer rural y su relación con el estado nutricional infantil en Honduras*: EAP Zamorano. [Asesores: Arie Sanders].

Caballero, J., 2021. *Efecto de la bioestimulación de salvado de arroz y harina de soya con enzimas y microorganismos en la producción de camarón (Litopenaeus vannamei) en Honduras*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7160. [Asesores: Paz, Patricio; Maldonado, Luis].

Cabrera, J., 2020. I*ncidencia de aflatoxinas y fumonisinas en grano, masa y tortillas de maíz en cuatro municipios del departamento de Lempira, Honduras*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6721. [Asesores: Espinal, Raúl; Maldonado, Luis].

Chuquillanqui, J., 2023. *Agricultura sostenible en América Latina: un estudio de percepciones de los graduados de la EAP Zamorano*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7508. [Asesores: Sanders, Arie; Rafael L., Luis].

Correa, L., 2024. *Una perspectiva de género en el manejo de la roya en comunidades cafetaleras de Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7775. [Asesores: Sanders, Arie; Bonilla, Sara].

Cruz, A., 2022. *Evaluation of an integrated crop livestock system of sorghum-dolichos bean-maize and calves in Zamorano, Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7198.2. [Asesores: Moncada, Marielena; Sierra, Alejandra].

Curruchich, W., 2023. *Desarrollo de variedades de maíz con tolerancia a sequía y resistencia a la mancha de asfalto*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7509. [Asesores: Colbert, Raphael; Rodríguez, Iveth].

D' Vicente, V., 2022. *Efecto de cinco niveles de fertilización nitrogenada en la producción de cuatro variedades de maíz bajo dos sistemas de labranza*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7199.2. [Asesores: Pineda, Renán].

Del Valle, M., 2021. *Herramienta de evaluación de política pública para promover la Agricultura Tropical Sostenible*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7161. [Asesores: Sanders, Arie; Rosas, Juan C].

Enriquez, J. P., 2021. *Eating behaviors, adherence, and acceptance of a healthy and sustainable diet in Zamorano*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7162. [Asesores: Hernández, Adriana; Espinoza, Sandra].

Espinoza, A., 2021. *Caracterización fenotípica de accesiones de sorgo para la adaptación a condiciones de sequía del Corredor Seco Centroamericano*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7163. [Asesores: Colbert, Raphael; Rodríguez, Iveth].

Flores, F., 2023. *Caracterización fenotípica de accesiones de tomate en condiciones a campo abierto y macrotúnel*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7481. [Asesores: Avellaneda, Carolina; Ramírez, Hugo; Colbert, Raphael].

Gamez, M., 2024. B*eneficios del uso de biofertilizantes a base de bacterias endémicas en el crecimiento del cultivo de maíz*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7776. [Asesores: Trabanino, Rogelio; Guzman, Sayda].

Gómez, A., 2024. *Evaluación del rendimiento del cultivo de banano a través de la aplicación de aprendizaje automático ("Machine Learning") en Urabá, Colombia*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7778. [Asesores: Espinal, Raúl; Sandoval, Luis].

Gómez, M., 2021. *Caracterización fenotípica de accesiones de maíz para la adaptación a la sequía*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7164. [Asesores: Colbert, Raphael; Rodríguez, Iveth].

González, G., 2024. *Efecto a corto plazo del biocarbón en las características químicas de un suelo fuertemente ácido y la productividad de tomate*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7777. [Asesores: Peña, Ricardo; Rosas, Juan C].

Gonzalez de Leon, A., 2022. *Determinación del efecto del diferencial hídrico del suelo en la producción de frijol mediante sensores remotos:* EAP Zamorano. Honduras. https://hdl.handle.net/11036/7207.2. [Asesores: Arévalo de Gauggel, Gloria; Sandoval, Luis].

Guacho, L., 2023. P*ropuesta de un estándar para la evaluación de sostenibilidad en sistemas silvopastoriles en Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7507. [Asesores: Velasquez B, Manuel; Granadino, Marco; Flores, Juan].

Guardado, W., 2022. *Macrofauna edáfica como indicador clave para identificar elementos de una agricultura y ganadería sostenible*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7209.2. [Asesores: van den Berghe, Eric; Tercero, José].

Gutierrez, M., 2020. *Eficiencia de dietas nutracéuticas y manejo de camas sobre las pérdidas de N y P en pollos de engorde*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6727. [Asesores: Parrado, Alicia; Martinez, Yordan].

Hernandez, E., 2023. *Impacto de los ingredientes alternativos sobre la productividad y porciones comestibles de gallinas ponedoras y pollos de engorde*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7510. [Asesores: Martinez, Yordan].

Holguín, J., 2020. *Evaluación del efecto de un diseño hidrológico en Línea Clave en pasturas de la Unidad de Reemplazos de Ganado de Leche en Zamorano, Honduras*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6722. [Asesores: Moncada, Marielena; Arévalo de Gauggel, Gloria].

Huamaní, D., 2023. *Percepciones de caficultores sobre mamíferos silvestres en Honduras y Perú*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7500. [Asesores: van den Berghe, Eric].

Huarquila, W., 2022. *Modelos de predicción del rendimiento de la caña de azúcar a partir de índices multiespectrales de vegetación en Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7210.2. [Asesores: Arévalo de Gauggel, Gloria; Avellaneda, Carolina].

Igeler, W., 2023. *Desarrollo de poblaciones F2 de sorgo con potencial de adaptación para la producción en las condiciones del Corredor Seco Centroamericano*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7512. [Asesores: Colbert, Raphael; Rodríguez, Iveth].

Jarquín, L., 2024. *Estado nutricional, costos dietéticos y barreras para una alimentación saludable en escolares de Alauca, Honduras, 2023*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7779. [Asesores: Sandoval, Luis; Hernández, Adriana; Morales, Sarahí].

Jerez, C., 2022. Importancia del empoderamiento de la mujer en la nutrición infantil: Estudio de caso Guatemala: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7211.2. [Asesores: Sanders, Arie; Bonilla, Sara].

Jiménez, F., 2021. *Evaluación de la resistencia de accesiones de maíz a la mancha de asfalto mediante criterios epidemiológicos y sensores remotos*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7165. [Asesores: Avellaneda, Carolina; Henríquez, Lenín; Cruz, Christian; Rodríguez, Iveth].

Landa, J., 2020. *Efecto de prácticas alternativas de control de malezas y nutrición en variables agronómicas y en el manejo sostenible del cultivo de la caña de azúcar (Saccharum officinarum)*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6728. [Asesores: Pineda, Renán; Avellaneda, Carolina; Rendón, Julio].

Lemus, D., 2022. *Resistencia genética del frijol común al gorgojo mexicano de almacén Zabrotes subfasciatus [Boheman (Coleóptera: Chrysomelidae)]*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7213.2. [Asesores: Espinal, Raúl; Colbert, Raphael; Rodríguez, Iveth].

Lopez, L., 2024. *Fictitious foods as an increment source for the predatory mite Neoseiulus cucumeris (Oudemans) (Acari: Phytoseiidae), agent of biological pest control*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7781. [Asesores: Trabanino, Rogelio; Barroso, Geovanny; Cocom, Miguel].

Machado, O., 2020. *Efecto de la reducción de proteína cruda en la dieta sobre el rendimiento productivo y de canal e impacto ambiental en pollos de engorde*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6724. [Asesores: Martinez, Yordan; Pacheco, Wilmer; Mejía, Leonel; Naranjo, Víctor].

Macías, P., 2024. *Desarrollo de poblaciones mejoradas de maíz con tolerancia a sequía y resistencia a la mancha de asfalto y roya tropical*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7782. [Asesores: Cerna, Marvin; Rodríguez, Iveth].

Madriz, N., 2022. *Efecto de escenarios climáticos futuros en la disponibilidad de agua de cultivos de Zamorano*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7218.2. [Asesores: Ordoñez, José; Henríquez, Lenín].

Mamani, B., 2022. *Knowledge, preferences and willingness to pay for coffee sustainability attributes in Honduran consumers*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7214.2. [Asesores: Sandoval, Luis; Palma, Marco].

Marín, D., 2020. *Estimación preliminar productiva y modelada de las emisiones y mitigación de gases de efecto invernadero en sistemas de producción de leche de Honduras*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6725. [Asesores: Matamoros, Isidro; Ramírez, Carlos A].

Martínez, A., 2022. *Evaluación del bienestar animal en las Unidades de ganado lechero y de ganado porcino mediante protocolos Welfare Quality ®en Zamorano, Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7217.2. [Asesores: Moncada, Marielena; Jiménez, Maria].

Melara, E., 2021. *Caracterización in vitro y evaluación in vivo de una cepa nativa de Lactobacillus reuteri con efecto probiótico en pollos de engorde*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7166. [Asesores: Martinez, Yordan; Avellaneda, Carolina].

Meléndez, D., 2024. *Satisfacción con la vida e intención de migrar: un análisis holístico de la juventud rural en la agricultura hondureña*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7784. [Asesores: Morales, Sarahí; Sandoval, Luis].

Molina, M., 2021. *Caracterización de la fenología y efectos de densidades de siembra y podas en la producción hortícola sustentable de jícama [Pachyrhizus erosus (L.) Urb.]*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7167. [Asesores: Ramírez, Hugo; Sørensen, Marten].

Montoya, G., 2024. *Efecto de Azospirillum spp. en el crecimiento y desarrollo de maíz, sorgo y arroz bajo tres niveles de fertilización*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7785. [Asesores: Rosas, Juan C; Pineda, Renán].

Navarro, E., 2023. *Voz de la mujer marcalense en la producción del café bajo prácticas sostenibles: estudio de caso*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7482. [Asesores: Sanders, Arie; Bonilla, Sara].

Osorto, E., 2021. *Producción de lechuga en acuaponía con adición de fertilizantes orgánicos* líquidos y bacterias promotoras de crecimiento: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7168. [Asesores: Sierra, Alejandra; Paz, Patricio; Ramírez, Hugo].

Padilla, G., 2022. *Monitoreo de Huanglongbing en limón "Tahití" por medio de imágenes multiespectrales*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7220.2. [Asesores: Avellaneda, Carolina; Henríquez, Lenín].

Paiz, N., 2024. *Caracterización del carbono orgánico y la microbiota edáfica en diferentes sistemas de producción en Zamorano, Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7786. [Asesores: Peña, Ricardo; Avellaneda, Carolina; Peña, Diego].

Palomino, E., 2024. *Validación de la resistencia de líneas de frijol común a los daños causados por gorgojos de almacén en fincas de agricultores en Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7787. [Asesores: Espinal, Raúl; Rodríguez, Iveth].

Pierre, F., 2023. *Comportamiento agronómico de variedades criollas y mejoradas de maíz en un suelo "typic ustifluvent" de baja fertilidad*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7483. [Asesores: Rodríguez, Iveth; Colbert, Raphael].

Puerto, C., 2020. *Caracterización de la mancha de asfalto en maíz (Zea mays L.) mediante el uso de herramientas de detección y control en condiciones de campo*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6732. [Asesores: Henríquez, Lenín; Avellaneda, Carolina; Arévalo de Gauggel, Gloria].

Ramos, B., 2020. *Efecto de fungicidas minerales aplicados al fruto del cacao (Theobroma cacao L.) para el control de Moniliophthora roreri y Phytophthora palmivora*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6729. [Asesores: Pineda, Renán; Avellaneda, Carolina; Rivera, José Mauricio; Díaz, Francisco].

Redrovan, D., 2022. *Elaboración de protocolos para lapr producción de forraje verde hidropónico de baja tecnología*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7224.2. [Asesores: Moncada, Marielena; Sierra, Alejandra].

Retes, R., 2021. *Efecto del desmucilaginado y remojo en agua con ácidos orgánicos en las características físico-químicas y sensoriales del café*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7169. [Asesores: Cardona, Jorge; Maldonado, Luis].

Ricaurte, L., 2023. *Efecto de la cobertura con residuos de sorgo y leguminosas en el control de malezas y rendimiento de maíz*: EAP Zamorano. Honduras. [Asesores: Pineda, Renán].

Rosas, D., 2021. *Manejo diferencial de los suelos mediante agricultura de precisión y convencional para la producción de semilla de frijol y sorgo*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7170. [Asesores: Arévalo de Gauggel, Gloria; Pineda, Renán].

Rosero, J., 2024. *Control biológico de los nematodos Meloidogyne spp. y Pratylenchus spp. en cultivos de sandía (Citrullus lanatus) y plátano (Musa paradisiaca)*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7788. [Asesores: Trabanino, Rogelio; Espinal, Raúl; Moreira, David; Cocom, Miguel].

Solano, F., 2024. *Desarrollo de variedades mejoradas de sorgo mediante la selección de familias segregantes por tolerancia a sequía y resistencia a pulgón amarillo y la roya*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7789. [Asesores: Rosas, Juan C; Rodríguez, Iveth].

Tax, V., 2021. *Adopción de prácticas de Agricultura Sostenible Adaptadas al Clima: Estudio de caso en Honduras*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7171. [Asesores: Sanders, Arie; Cárcamo, Jorge].

Tello, A., 2021. *Efecto en la cobertura de residuos de cosecha en la producción de maíz orgánico y no orgánico bajo tres sistemas de labranza*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7172. [Asesores: Pineda, Renán; Ordoñez, José].

Vásquez, E., 2021. *Caracterización de la agrobiodiversidad y el manejo de los huertos familiares de San Andrés, Lempira*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7173. [Asesores: McLean, Francis; Sanders, Arie; Díaz, Rina].

Vera, D., 2021. *Susceptibilidad del hongo entomopatógeno Cordyceps fumosorosea a plaguicidas utilizados en el cultivo de tomate (Solanum lycopersicum L.) y su efectividad biológica sobre Bemisia tabaci (Gennadius)*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/7174. [Asesores: Trabanino, Rogelio; Avellaneda, Carolina].

Villamar, F., 2023. *Aplicación del Proceso de Diseño Ecológico (PDE) para una propuesta conceptual de Agricultura Regenerativa en Zamorano*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7514. [Asesores: van den Berghe, Eric; Espinoza A, Jorge].

Villamarín, W., 2022. *Optimización de la liberación, establecimiento y almacenamiento del ácaro depredador Amblyseius swirskii (Athias-Henriot) (Acari: Phytoseiidae)*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7228.2. [Asesores: Trabanino, Rogelio; Orozco, Jesús; Espinal, Raúl].

Villeda, E., 2022. *Efecto del arreglo espacial de siembra y la aplicación de ácidos húmicos y fúlvicos en la producción bajo el Sistema Intensivo del Cultivo de Arroz (SICA)*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7229.2. [Asesores: Pineda, Renán].

Wú, B., 2020. *Application of Functional Ice (FICE) to Reduce the Incidence of Spoilage Microorganisms on the Surface of Shrimp, Tilapia, and Chicken*: EAP Zamorano. Honduras. https://bdigital.zamorano.edu/handle/11036/6731. [Asesores: Márquez, Mayra; Morey, Amit; Sandoval, Luis].

Zelaya, E., 2024. *Sostenibilidad de fincas bovinas productoras de leche y de doble propósito en el Litoral Atlántico de Honduras*: EAP Zamorano. Honduras. https://hdl.handle.net/11036/7791. [Asesores: Trejo, Celia O; Morales, Sarahí].

Annex C

List of Publications

Arreola, L. R., Quiroz-Guzmán, E., Caballero, J. L., García, E. I. P., Murueta, J. H. C. y Carreño, F. L. G. (2023). Shrimp Hepatopancreatic Crude Enzymes as Aids in Rice Bran Hydrolysis: Potential Contributors to Sustainable Aquaculture. *Turkish Journal of Fisheries and Aquatic Sciences*, 23(9). https://doi.org/10.4194/TRJFAS22332

Avain A, A., Hernandez L, E. G., Navarro R, E. S., Antúnez M, G. N. y Hernandez, A. (2022). Desperdicios alimentarios y su impacto en la seguridad alimentaria y el ambiente. *REDICINAySA*, 11(5). https://www.researchgate.net/publication/366739721_Desperdicios_alimentarios_y_su_impacto_en_la_seguridad_alimentaria_y_el_ambiente/references#fullTextFileContent

Becerra A, J. L., Flores P, F. C., Villamar, F. y Hernández, A. (2023). Avicultura de traspatio: modelo alternativo de producción avícola que contribuye a la seguridad alimentaria y nutricional en Honduras. *Innovare: Revista De Ciencia Y Tecnología*, 12(1), 39–41. https://doi.org/10.5377/innovare.v12i1.15962

Cabrera M, J., Maldonado, L., Bianchini, A. y Espinal, R. (2021). Incidence of aflatoxins and fumonisins in grain, masa and maize tortillas in four municipalities in the department of Lempira, Honduras. *Heliyon*, 7(12), e08506. https://doi.org/10.1016/j.heliyon.2021.e08506

Enriquez, J. P [Jean P], Hernandez, A., Achila-Godinez, J. y Espinoza, S. K [S K] (2021). Implementation of Healthy and Sustainable Dishes in a Multicultural University Cafeteria: A Pilot Study Using Sensory Science. *Austin Journal of Nutrition & Metabolism*, 8(3). https://doi.org/10.26420/austinjnutrmetab.2021.1110

Enriquez, J. P [Jean Pierre] (2020). Food Self-Sufficiency: Opportunities and Challenges for the Current Food System. *Biomedical Journal of Scientific & Technical Research*, 31(2). https://doi.org/10.26717/BJSTR.2020.31.005061

Enriquez, J. P [Jean Pierre] y Archila-Godinez, J. C. (2022). Social and cultural influences on food choices: A review. *Critical Reviews in Food Science and Nutrition*, 62(13), 3698–3704. https://doi.org/10.1080/10408398.2020.1870434

Enriquez, J. P [Jean Pierre], Bodden, S. y Hernandez, A. (2021). Sustainable Diets, A Way to Improve and Maintain Eating Behaviors and Health in Times of COVID-19 in First-Year University Students. *Austin Journal of Nutrition and Food Sciences*, 9(1). https://doi.org/10.26420/AustinJNutriFoodSci.2021.1150

Enriquez, J. P [Jean Pierre], Hernández, A. y Bodden, S. (2021). Unhealthy Eating Behaviors of First Year Latin-American Students, An Opportunity for Sustainable Nutritional Interventions. *Biomedical Journal of Scientific & Technical Research*, 34(5). https://doi.org/10.26717/BJSTR.2021.34.005602

Enriquez, J. P [Jean Pierre] y Hernandez Santana, A. (2023). Student Responses to Switching to Online Nutritional Interventions During Pandemic in a Latin-American University. *Building Healthy Academic Communities Journal*, 7(1), 23–30. https://doi.org/10.18061/bhac.v7i1.9342

Enriquez, J. P [Jean Pierre], Hernandez Santana, A. y Del-Cid, D. Y. (2024). Impact of Nutritional Education Intervention on Food Choice Motivations and Eating Behaviors Among Latin American University Students. *American Journal of Health Education*, 1–10. https://doi.org/10.1080/19325037.2024.2338072

Enriquez, J. P [Jean Pierre], Hernandez Santana, A., Espinoza, S. K [Sandra Karina] y Archila-Godinez, J. C. (2023). Sustainable and healthy food consumption patterns in a multicultural university cafeteria by plate waste visual estimation. *Journal of Foodservice Business Research*, 1–21. https://doi.org/10.1080/15378020.2023.2240206

Enriquez, J. P [Jean Pierre] y Hernández-Santana, A. (2021). Influencia de intervenciones educativas sobre nutrición y sostenibilidad en universitarios Ecuatorianos residentes en Honduras. *La Granja: Revista De Ciencias De La Vida*, 34(2), 80–90. https://doi.org/10.17163/lgr.n34.2021.05

Enríquez, J. P [Jean Pierre], Retes-Cálix, R. F. y Vásquez-Reyes, E. F. (2020). Importancia, genética y evolución del café en Honduras y el mundo. *Innovare: Revista De Ciencia Y Tecnología*, 9(3), 149–155. https://doi.org/10.5377/innovare.v9i3.10649

Enríquez, J. P [Jean Pierre], Vera-Martínez, D. J. y Hernández Santana, A. (2020). Logro del Hambre Cero en Ecuador: reflexiones sobre los programas de nutrición. *Innovare: Revista De Ciencia Y Tecnología*, 9(3), 163–165. https://doi.org/10.5377/innovare.v9i3.10651

Espinoza A, A., Colbert, R., Rodríguez, I. y Rosas, J. C [Juan Carlos] (2021). Caracterización fenotípica de accesiones de sorgo para la adaptación a condiciones de sequía del Corredor Seco Centroamericano. *Ceiba, Zamorano Investiga*, 22–35. https://revistas.zamorano.edu/index.php/CEIBA/article/view/1266/1202

Flores, F., Ramirez-Guerrero, H. O., Maxwell, L., Eybishitz, A., Barchenger, D. W. y Avellaneda, M. C [M. Carolina] (2024). Adaptability and Yield Performance of Introduced Tomato Lines under Greenhouse and Open Field Conditions in Honduras. *HortScience,* 59(8), 1041–1048. https://doi.org/10.21273/HORTSCI17753-24

Flores Pablo, F. y Ramírez Guerrero, H. O. (2023). Tomates y papas en una misma planta: propuesta de innovación hortícola para la seguridad alimentaria tropical. *Innovare: Revista De Ciencia Y Tecnología*, 12(3), 127–129. https://doi.org/10.5377/innovare.v12i3.17164

Fromm, I., Reiche, A., Sauceda, D. y Rivera, E. (2022). Social, environmental, and COVID-19 pandemic-related effects on women's food security and health in Honduras. *SN Social Sciences*, 2(9), 187. https://doi.org/10.1007/s43545-022-00448-y

Gómez, M., Colbert, R., Rodríguez, I. y Rosas, J. C [Juan Carlos] (2021). Comportamiento agronómico de accesiones de maíz de Honduras bajo estrés de sequía. *Ceiba, Zamorano Investiga*, 36–51. https://revistas.zamorano.edu/index.php/CEIBA/article/view/1267/1203

Gómez, M., Rosas, J. C [Juan Carlos], Humphries, S [Sally.], Jiménez, J., Barahona, M., Ávila, C., Orellana, P. y Sierra, F. (2021). Pushing back against bureaucracy. En O. T. Westengen y T. Winge (Eds.), *Issues in agricultural biodiversity. Farmers and plant breeding: Current approaches and perspectives* (Vol. 1, p. 16). Routledge, Taylor & Francis Group; Earthscan, from Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9780429507335-7/pushing-back-bureaucracy-marvin-gomez-juan-carlos-rosas-sally-humphries-jose-jimenez-merida-barahona-carlos-avila-paola-orellana-fredy-sierra

Gongora-Canul, C. C., Puerto, C [Carlos], Jiménez-Beitia, F. E., Telenko, D. E., Kleczewski, N [Nathan], Rosas, J. C [Juan C], Avellaneda, C., Sanders, A., Rodriguez, I. Y [Iveth Y.], Goodwin, S. B., Henriquez-Dole, L. E., Fernandez-Campos, M., Lee, D., Cruz, A. P [Andres P.] y Cruz, C. D. (2024). Comparing tar spot epidemics in high-risk areas in the United States and Honduras. *Canadian Journal of Plant Pathology*, 46(3), 288–305. https://doi.org/10.1080/07060661.2023.2300077

Góngora-Canul, C., Jiménez-Beitia, F. E., Puerto-Hernández, C., Avellaneda C, M. C., Kleczewski, N [Nathan], Telenko, D. E. P., Shim, S., Solórzano, J. E., Goodwin, S. B., Scofield, S. R. y Cruz, C. D. (2023). Assessment of symptom induction via artificial inoculation of the obligate biotrophic fungus Phyllachora maydis (Maubl.) on corn leaves. *BMC Research Notes*, 16(1), 69. https://doi.org/10.1186/s13104-023-06341-y

Guacho, L. N., Atehortua, M. K., Curruchich, W. A. y Hernández, A. (2023). Consecuencias de la reducción de cultivos andinos: situación nutricional de tres comunidades Kichwa de Ecuador. Innovare: R*evista De Ciencia Y Tecnología*, 12(1), 16–22. https://doi.org/10.5377/innovare.v12i1.15954

Guacho, L. N., Atehortua, M. K., Navarro Roque, E. S., Hernández, A., Ricaurte, L., Antúnez Méndez, G. N., Villamar, F., Chuquillanqui, J., Huamaní, D., Avain Albelo, A., Curruchich, W. A., Flores Pablo, F. C., Hernández Lozano, E. G., Pierre, F., Becerra Abril, J. L., Benavides Bernal, S. y Igeler, W. (2023). Retos para la transición a la sostenibilidad del sistema alimetario en Honduras. *Ceiba*, 56(2), 105–120. https://doi.org/10.5377/ceiba.v56i2.17121

Hernández, A., Bustillo, Y. y Jarquín, L. D. (2024). Consumo alimenticio y actividad física de escolares del área rural de Honduras. *Ceiba,* 57(1), 73–88. https://doi.org/10.5377/ceiba.v57i1.18143

Hernández, A., Gutierrez-Soto, B., Barrios, A. y Navarro Roque, E. (2023). Hacia una agroindustria alimentaria que nutra y contribuya a la sostenibilidad. *Ceiba*, 56(2), 121–132. https://doi.org/10.5377/ceiba.v56i2.17125

Hernandez Santana, A., Bodden, S., Rojas Aleman, D., Enríquez, J. P [Jean Pierre], Di Iorio, A. B. y Hernández-Santana, A. (2020). Evaluation of the Nutritional Quality of Processed Foods in Honduras: Comparison of Three Nutrient Profiles. *International Journal of Environmental Research and Public Health*, 17(19). https://doi.org/10.3390/ijerph17197060

Hernandez-Santana, A., Motiño, S., Enríquez, J. P [Jean P] y Lanza-Aguilar, S. B. (2021). Maternal Nutrition Status and Human Milk Composition of DHA and AA Fatty Acids in Breastfeeding Honduran Women. *Austin Journal of Nutrition & Metabolism*, 8(3). https://doi.org/10.26420/austinjnutrmetab.2021.1109

Igeler Cáceres, W. R. y Bernal, S. B. (2023). Seguridad alimentaria y nutricional en el sistema educativo básico hondureño: un enfoque desde el hogar. Innovare: *Revista de Ciencia y Tecnología*. Publicación en línea avanzada. https://doi.org/10.5281/zenodo.10574071

Jerez Sarceño, C., Bonilla, S. y Sanders, A. (2023). El impacto del empoderamiento de las mujeres en la nutrición infantil en Guatemala. *Ciencias Sociales Y Humanidades*, 10(2). https://doi.org/10.36829/63CHS.v10i2.1513

Landaverde, R., Rodriguez, M. T., Niewoehner-Green, J., Kitchel, T. y Chuquillanqui, J. (2022). Climate Change Perceptions and Adaptation Strategies: A Mixed Methods Study with Subsistence Farmers in Rural Peru. *Sustainability*, 14(23), 16015. https://doi.org/10.3390/su142316015

Loaiza Briceño, S. D., Sanders, A. y Carcamo, J. (2024). Gobernanza hídrica y acción climática: una perspectiva experimental desde el corredor seco hondureño. *Ceiba*, 57(1), 2–28. https://doi.org/10.5377/ceiba.v57i1.18137

Mamani Escobar, B., Redrovan, D., Villeda, E. y Hernández Santana, A. (2021). ¿Somos conscientes del efecto de las redes sociales en nuestra nutrición? *Innovare: Revista De Ciencia Y Tecnología*, 10(3), 178–180. https://doi.org/10.5377/innovare.v10i3.12990

Mamani Escobar, B., Sandoval, L., Palma, M. A., Carpio, C. y Garcia, M. D. (2023). Coffee sustainability attributes in developing countries: the Honduran domestic coffee market. *International Food and Agribusiness Management Review*, 26(4), 673–689. https://doi.org/10.22434/IFAMR2022.0126

Marín López, D., Matamoros Ochoa, I. A. y Ramírez Restrepo, C. A. (2022). Dinámicas de producción y emisiones modeladas de gases de efecto invernadero en sistemas regionales de producción lechera de Honduras. *Revista De La Facultad De Medicina Veterinaria Y De Zootecnia*, 69(1). https://doi.org/10.15446/rfmvz.v69n1.101526

Melara, E. G., Avellaneda, M. C [Mavir Carolina], Rondón, A. J., Rodríguez, M., Valdivié, M. y Martínez, Y. (2023). Characterization of Autochthonous Strains from the Cecal Content of Creole Roosters for a Potential Use as Probiotics. *Animals : An Open Access Journal from MDPI*, 13(3). https://doi.org/10.3390/ani13030455

Melara, E. G., Avellaneda, M. C [Mavir Carolina], Valdivié, M., García-Hernández, Y., Aroche, R. y Martínez, Y. (2022). Probiotics: Symbiotic Relationship with the Animal Host. *Animals*, 12(6). https://doi.org/10.3390/ani12060719

Molina, D. S., Gutierrez, J. B., Machado, O. D., Mas, D. y Martinez, Y. (2019). Nutraceutical Effect of Ganoderma lucidum Fungus on Neonatal Broilers Diet. I*nternational Journal of Poultry Science*, 18(12), 641–647. https://doi.org/10.3923/ijps.2019.641.647

Pierre, F., Arévalo Castro, F. J., Rodriguez, I. Y [Iveth Yassmin], Colbert, R. W. y Rosas, J. C [Juan Carlos] (2023). Respuesta de variedades criollas y mejoradas de maíz a la fertilización e inoculación con hongos micorrizas-arbusculares en un suelo de baja fertilidad. *Ceiba*, 56(2), 70–89. https://doi.org/10.5377/ceiba.v56i2.17118

Pierre, F., Rodriguez, I. Y [Iveth Yassmin], Colbert, R. W. y Rosas, J. C [Juan Carlos] (2023). Comportamiento agronómico de variedades criollas y mejoradas de maíz en un suelo de baja fertilidad. *Ceiba*, 56(1), 16–30. https://doi.org/10.5377/ceiba.v56i1.16352

Puerto H, C. E. y Avellaneda, C. (2021). Epidemiología de la mancha de asfalto en maíz bajo diferentes estrategias de manejo. *Ceiba, Zamorano Investiga*, 65–82. https://revistas.zamorano.edu/index.php/CEIBA/article/view/1269/1205

Rosas V, D. A., Arévalo de Gauggel, G. y Pineda, R. (2021). Manejo diferencial de suelos mediante el uso de prácticas de agricultura de precisión para la producción de semilla de frijol y sorgo. *Ceiba, Zamorano Investiga*, 83–101. https://revistas.zamorano.edu/index.php/CEIBA/article/view/1270/1206

Tax S, V. M., Sanders, A. y Cárcamo, J. (2021). Adopción de prácticas de agricultura sostenible adaptadas al clima: estudio de caso en Honduras. *Ceiba, Zamorano Investiga*, 1–21. https://revistas.zamorano.edu/index.php/CEIBA/article/view/1265/1201

Ullaguari, J. X., Landaverde, R., Sanders, A. y Zickafoose, A. (2023). Farmer-producer organizations during the COVID-19 pandemic: Examining the role of organization-producer relationships on coping, resiliency, and effectiveness. *Advancements in Agricultural Development*, 4(3), 131–145. https://doi.org/10.37433/aad.v4i3.331

Valle-Torres, J., Ross, T. J., Plewa, D., Avellaneda, M. C [M. C.], Check, J., Chilvers, M. I., Cruz, A. P [A. P.], Dalla Lana, F., Groves, C., Gongora-Canul, C., Henriquez-Dole, L., Jamann, T., Kleczewski, N [N.], Lipps, S., Malvick, D., McCoy, A. G., Mueller, D. S., Paul, P. A., Puerto, C [C.], . . . Cruz, C. D. (2020). Tar Spot: An Understudied Disease Threatening Corn Production in the Americas. *Plant Disease*, 104(10), 2541–2550. https://doi.org/10.1094/PDIS-02-20-0449-FE

Vásquez Reyes, E. F., Retes Cálix, R. F. y Hernández Santana, A. (2020). Diversificación agrícola, sostenibilidad y seguridad alimentaria y nutricional en el occidente de Honduras. Innovare: *Revista De Ciencia Y Tecnología*, 9(3), 169–171. https://doi.org/10.5377/innovare.v9i3.10653

Annex D

Faculty

Name	Department	Courses
Argueta, Syntia	Associated Dean's Office for Academic Quality and Management	Teaching methods in agricultural education
Avellaneda, Carolina	Agronomic Engineering	Plant protection
Bravo, Maria	Agronomic Engineering	Agricultural biotechnology
Cárcamo, Jorge	Graduate Program	Natural resource economics and policy
Colbert, Raphael	Agronomic Engineering	Agricultural biotechnology
Cortés, Victoria	Environment and Development	Sustainable energy
de Gauggel, Gloria	Agribusiness	Seminar: Current topics in agriculture and food I
Espinal, Raúl	Agrifood Industry	Statistical methods and experimental design
Henríquez, Lenin	Environment and Development	Agriculture and climate change Water management for agriculture
Hernandez, Adriana	Agrifood Industry	Human nutrition in agriculture
Komar, Oliver	Environment and Development	Agroecology
Maier, Ana	Agribusiness	Teaching methods in agricultural education

Name	Department	Courses
Márquez, Mayra	Agrifood Industry	Food safety program
McLean, Francis Denisse	Graduate Program	Master's thesis I Sustainable agricultural development Seminar-workshop: Trends in agriculture Seminar: Current topics in agriculture and food II
Moncada, María Elena	Agronomic Engineering	Sustainable animal production systems
Morales, Sarahi	General Curriculum	Teaching methods in agricultural education
Murillo, José Oscar	Graduate Program	Seminar-workshop: Trends in agriculture Seminar: Current topics in agriculture and food I and II Agricultura y Alimentación II
Orozco, Jesus	Agronomic Engineering	Plant Protection
Parrado, Carmen Alicia	Environment and Development	Agroecology
Pejuan, Wolfgang	Agribusiness	Statistical methods and experimental design
Peña, Ricardo	Agronomic Engineering	Agroecology
Pineda, Renán	Agronomic Engineering	Crop physiology, nutrition and management
Reconco, Rommel	Agribusiness	Agrifood projects evaluation

Name	Department	Courses
Rosas, Juan Carlos	Graduate Program	Master's thesis II to VI
Sanders, Arie	Graduate Program	Master's thesis I Sustainable agricultural development
Sandoval, Luis	Agribusiness	Econometrics
Trejo, Celia	Agronomic Engineering	Sustainable animal production systems
Van der Berghe, Eric	Agronomic Engineering	Agroecology

Literature Cited

1. Brunold A, Ohlmeier B. Civic Education for Sustainable Development of UNESCO – Decade 2005–2014. Discourse and Communication for Sustainable Education 2022; 13(2):79–90.

2. Leal Filho W, Portela de Vasconcelos CR. Handbook of Best Practices in Sustainable Development at University Level. Cham: Springer International Publishing; 2022.

3. Hart DD, Bell KP, Lindenfeld LA, Jain S, Johnson TR, Ranco D et al. Strengthening the role of universities in addressing sustainability challenges: The Mitchell Center for Sustainability Solutions as an institutional experiment. Ecology and Society 2015; 20(2).

4. Kopp RE. Land-grant lessons for Anthropocene universities. Climatic Change 2021; 165(1-2).

5. Sutton WR, Lotsch A, Prasann A. Recipe for a Livable Planet: Achieving Net Zero Emissions in the Agrifood System. Agriculture and Food Series. Conference Edition. Washington DC: World Bank. Available from: URL: https://hdl.handle.net/10986/41468.

6. Pretty J. Intensification for redesigned and sustainable agricultural systems. Science 2018; 362(6417).

7. Mol A, Spaargaren G, Sonnenfeld DA. Ecological Modernization Theory: Taking Stock, Moving Forward. In: Lockie S, Sonnenfeld DA, Fisher D, editors. Routledge international handbook of social and environmental change. London, New York: Routledge/Taylor & Francis Group; 2014. p. 15–30 (Routledge international handbooks).

8. Dryzek. The Politics of the Earth: Environmental Discourses. Oxford: Oxford University Press; 2013.

9. Fresco LO. The new green revolution: Bridging the gap between science and society. Current Science 2015; 109(3):430–8.

10. Horlings LG, Marsden TK. Towards the real green revolution?: Exploring the conceptual dimensions of a new ecological modernisation of agriculture that could 'feed the world'. Global Environmental Change 2011; 21(2):441–52.

At Zamorano, we provide students at the undergraduate and graduate levels with the skills and knowledge needed to address critical challenges in agriculture, agribusiness, processing, and environmental sustainability. We focus on finding practical solutions to climate change, food security, and biodiversity conservation, aligning with the United Nations Sustainable Development Goals.

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