

## Memory of the course:

### **“Applied transformative systems research for sustainable development”**



This course is part of project Transformative Research and Capacity Building in the Education Sector to Protect Livelihoods and Biodiversity in Costa Rica 2021-2024, funded by the German Academic Exchange Service (DAAD) and jointly executed between the Universidad Técnica Nacional (UTN) of Costa Rica and the University of Osnabrück (UOS) in Germany.

### **Organizing Committee:**

Andrés Araya Araya, UTN

María Fernanda Arias Araya, UTN

Melissa Camacho Esquivel, UTN

Johannes Halbe (facilitator), UOS

Marijke Kalinowski, UOS

Jennifer Sánchez Acosta, UTN

Maynor Vargas Vargas, UTN

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## Table of contents

Introduction .....	5
Sustainable management of the Quebrada de Barro micro-watershed.....	7
Andrés Araya Araya	
Sustainable agroindustrialization of a natural product under controlled environmental conditions .....	8
Arlette Jiménez Silva	
The perceptions of waste management in Paquera, Puntarenas, Costa Rica .....	9
Daylin Alejandra Vega Mojica	
Agua de Poás (Poás Water).....	10
Elemer Briceño Elizondo	
Generation Z and the sustainability vision: a study of university students from Guanacaste, Costa Rica.....	11
Héctor Andrés Canossa Montes de Oca	
Research management in UTN as a tool to promote research relevance to social and economic dimension .....	12
Jennifer Sánchez Acosta	
Avoiding Urbanization of Coffee Farms.....	13
José Pablo Molina Sibaja	
Challenges and Solutions in Integrated Wastewater Management on Dairy Farms .....	14
María Fernanda Arias Araya	
Sustainable Ecotourism in Bajo La Paz: Balancing Conservation and Community Development.....	15
Maynor Alberto Vargas Vargas	
Driving the Growth of Bio and Nanopesticides as Eco-Friendly Agricultural Alternatives.. .....	16
Gabriela Montes de Oca Vásquez & Melissa Camacho Elizondo	
AquaEcosystem .....	17
Melissa Montero Alvarado	
Exploratory Use of Artificial Intelligence to Create a Systemic View of the Gold Mining Situation in Crucitas, Costa Rica, based on an Interview with President Chaves .....	18
Sergio Arturo Cubero Mata	

Evaluation of the Strategic plan for aquaculture in Costa Rica 2024-2029 .....	19
Silvia Ramírez Flores	
Burning residual biomass in agriculture from agricultural crops .....	20
Mauren Rodríguez Castro & Yesenia Marín Quesada	
Epilogue.....	21

## Introduction

The following report compiles the work carried out by researchers from different regional campuses and university departments who participated in the course “Applied Transformative Systems Research for Sustainable Development,” which is part of the project “ransformative Research and Capacity Building in the Education Sector to Protect Livelihoods and Biodiversity in Costa Rica 2021-2024”. This project has been developed since 2021 between the National Technical University (UTN) in Costa Rica and the University of Osnabrück (UOS) in Germany.

This collaboration has facilitated the strengthening of UTN’s research activities through joint work between university researchers and high-level professionals, internationally recognized experts in fields complementary to the technical work of the institution, thus enhancing the scope of the research designs. This is the first specialized research course developed at our institution in international collaboration to create robust and innovative proposals.

During the course, participants had the opportunity to strengthen their research skills, applying the theoretical knowledge acquired to address current issues. Furthermore, the interaction with other researchers and UOS students allowed them to foster collaborative and interdisciplinary work.

Throughout this experience, the researchers developed their research project proposals related to local and global challenges faced in diverse areas such as agribusiness, ecotourism, water resource management, education, and engineering, demonstrating a commitment to generating sustainable and applicable solutions.

This document highlights the potential of the tools learned in project management, as well as the initiatives being developed by our researchers in various strategic areas that the university has been strengthening over the years.

MGAS. Eric Alvarado Barrantes

Vice Rector for Research and Transfer

Universidad Técnica Nacional





### Andrés Araya Araya

Master's Degree in Integrated Development of Irrigated Regions

Researcher

Center for Sustainable Development Studies (CEDS)

<https://orcid.org/0000-0003-2517-1298>

## Sustainable management of the Quebrada de Barro micro-watershed

The Quebrada de Barro is born in the central district of the canton of Alajuela, Costa Rica. According to observations, its water is polluted, as well as the protection zones present invasions, deforestation and contamination.

Faced with this challenge, CEDS initiated in 2024 the research "Research, transfer and learning model for the sustainable management of the Quebrada de Barro micro-watershed". Part of the objectives are related to the involvement of stakeholders present in the study area, so interviews were conducted with representatives of the Municipality of Alajuela, the community aqueduct Árbol de Guaria (ASADA) and the condominium Málaga, with the idea of describing the sustainable vision of the management of the micro-watershed in each case.

The results show that the vision of the ASADA gives priority to private and public participation, as well as the creation of a committee to monitor the state of the micro-watershed. Likewise, the vision of the Málaga Condominium prioritizes the consolidation of such a committee, but also the well-being of the inhabitants of the micro-watershed. On the other hand, the vision of the representative of the Municipality is focused on regulations and urban planning, but with a focus on harmony between the social and environmental dimensions.

Among the most significant lessons learned was the transition from linear thinking to a systemic, multi-causal thinking exercise. We also learned to approach from the vision or what we want to achieve and not so much to focus on the problem, which avoids pessimistic thinking schemes.



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**Arlette Jiménez Silva**

Master in Virtual Learning Environments  
Coordinator of a Program for Chemistry  
Laboratory Analysts for Quality Assurance  
Vice-Rectorate for Extension and Social  
Action, UTN

<https://orcid.org/0009-0007-8290-639X>

## Sustainable agroindustrialization of a natural product under controlled environmental conditions

This project is being carried out in the community of Bajo La Paz, San Ramón, Costa Rica, located near the last protected cloud forest in the western region.

To provide the community with a more sustainable economic alternative, we propose an elderberry agroindustrialization project. This initiative aims to generate income through the production of biofunctional and natural elderberry products. The project began with an exploratory investigation into the potential benefits and products derived from elderberry. Students in the Chemical Laboratory Technician Program for quality assurance conducted experimental activities using parts of the elderberry plant as raw material, including red, purple, and green fruits, leaves, and flowers.

The methodology included: Stakeholder analysis to identify key groups, Vision modeling to engage stakeholders, Causal Loop Diagram (CLD) construction, Fuzzy Cognitive Mapping (FCM) to quantify the CLDs and simulate different scenarios.

The identified stakeholders are the community of Bajo La Paz, tourist agents, financial companies, tourists, and macrobiotic stores. The project considers economic, environmental, and social aspects, seeking a balance between community's quality and a sustainable alternative to sugarcane cultivation. FCM simulations indicate that increasing green primary production, technological innovation, road infrastructure, and educational levels have a positive impact. The simulations highlight the critical role of road infrastructure, suggesting that improving access to the area may be crucial for developing the elderberry agroindustry.



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**Daylin Alejandra Vega Mojica**  
Master in Sanitary Engineering  
Researcher  
UTN Pacific Campus  
<https://orcid.org/0000-0001-6444-0089>

## The perceptions of waste management in Paquera, Puntarenas, Costa Rica

This Project analyze the different perceptions of waste management in the coastal community of Paquera, in Puntarenas. According with the law number 8839 and their regulations in Costa Rica, the district must prioritize actions to establish the collect waste system. The problem generated by the lack of trash pickup service for many years, it has caused different consequences in the environmental health and pollution. Additionally, the Waste Management Plan for the period 2018-2022 expired without being implemented and this situation promoted the searching for an institution who would collaborate in the updating, in this case the UTN.

The methodology applied was with individual interviews, in the modality online and face to face workshop. They recognize different causes, their consequences and possible solutions such as education, conservation, new leaderships, cadastral data update and the creation of mixed economy systems and the local bioeconomy. First phase was the baseline diagnostic and then, second phase will be the execution of the Action Plan (strategy of waste management) for the Municipal Waste Management Plan of Paquera district towards 2027. The Action Plan includes the proposal of tools for the execution, monitoring and control of the established activities, considering objectives, goals, activities, responsible and co-responsible parties, resources and indicators. The strategic axes it contains are: 1. Education, training, capacity building and information; 2. Economic or financial; 3. Institutional and organizational strengthening; and 4. Solid waste valorization.



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**Elemer Briceño Elizondo**

PhD Forest Sciences

Research and Transfer Coordinator

Central Campus UTN

<https://orcid.org/0000-0003-1053-7330>

## Agua de Poás (Poás Water)

The Poás river micro watershed (located between the Barva and Poás volcanoes reaching the confluence of the Grande river near the city of Alajuela) has high potential for developing high quality aquifers for an important urban region at the center of Costa Rica thus, its natural resources should be utilized adequately.

This is best done by proper land use planning; specifically, among the communities and water management districts within the sources of the Poas watershed. A diverse and complex landscape with 4 main settlements, home to an important coffee producing industry, including one of the 5 global Starbucks farms as well as water source for the cities therein and down mountain. This area needs an integrated participatory water management system in order to guarantee not only supply, but to enhance resilience in the face of climate change adversities. The objective of this project is to optimize watershed management through participatory work from stakeholders through information to implement and mitigation and adaptation strategies to climate change.

Stakeholder analysis and technical land use practices and infrastructure are necessary to guarantee that not only drought situations are addressed, but also adequate water collection and distribution even within extreme rain events, which can also deliver risk situations in the communities therein and out of the watershed.



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**Héctor Andrés Canossa Montes de Oca**

PhD in Business Sciences

Professor and Researcher

Business Management and Administration,  
Guanacaste campus, UTN

<https://orcid.org/0000-0003-0952-3193>

## Generation Z and the sustainability vision: a study of university students from Guanacaste, Costa Rica

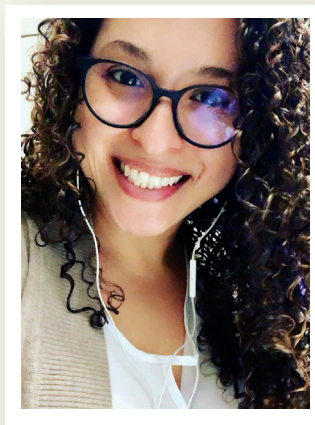
The project aims to understand Generation Z's sustainability vision in Guanacaste, Costa Rica, from the perspective of business administrators. The study will contribute to business sciences and education, optimize business strategies, and promote responsible consumption, highlighting the importance of Generation Z, who are increasingly relevant in production and consumption. This vision of sustainability should be promoted through education, communication, and awareness-raising of the environmental situation and its impact on society.

The methods used are document analysis, systemic thinking through mental models, and a survey. Using systemic thinking with causal loop diagrams constructed in interviews to analyze perceptions; fifteen students participated in this research, and the information was used to build the mental model. Document analysis helps to contextualize the research. Finally, the survey for primary data collection will apply a set of questions designed with respect to the research variables of the mental model that will be measured to generate data and fulfillment of the objectives set out in the research. The survey will be applied to a sample of 150 people from Generation Z located in Guanacaste.

The study aims to raise awareness about the urgency of a sustainability vision for the global future, share local perceptions, and influence decisions by involving stakeholders such as educational communities, citizens, Generation Z, private companies, and local government.



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### Jennifer Sánchez Acosta

Master's degree in program and project evaluation

Technical advisor

Vice-Rector of Research and Transfer

<https://orcid.org/0009-0007-7296-9231>

## Research management in UTN as a tool to promote research relevance to social and economic dimension

This research proposal was developed to study the relevance of the research activity in UTN to promote the best investment of its resources in the research practice that will attain transference and social and economic impact in different regions of Costa Rica. This is required given the context in which the research is conducted at UTN. From 2017 to 2023, 170 research projects were executed in UTN, this represents an investment close to 6 mill USD.

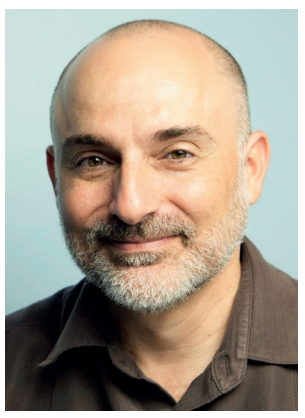
From 2017 to 2022, there was a reduction in the investment in research, as a result of the decrease on the investment in public higher education. As the public higher education system is being constantly questioned by its relevance and pertinence, the research activity in UTN is working towards a strategic model to attain the best possible outcomes, focusing not only on the academic products but also in the relevance of its activity to the beneficiaries from different sectors and areas.

This design integrates a methodology considering elements from the applied transformative systems research for sustainable development Course, proposing a study in 3 phases:

1. Interview process: Using strategic research areas goals as a start point. To explore Causal loop diagram as a tool to explain the relationship between research practice and its relevance to strengthen the impact in the society and the economic environment.
2. Diagram: To build the diagram I'll work from different levels, starting with institutional authorities in UTN, then researcher and research manager, and finally social actors. Both researchers and social actors will be selected from a sample of the total population.
3. Visioning: The vision modeling approach will be used with researchers and social actors, and comparing both visions would present a comparison that could help identify key points.



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**José Pablo Molina Sibaja**

Master in Educational Technology (MTE)  
Director of Educational Technology-  
CFPTE

<https://orcid.org/0009-0000-5546-9277>

## Avoiding Urbanization of Coffee Farms

Since the 19th century, coffee has represented one of the economic and identity pillars of the national population in Costa Rica, especially that of the Central Valley. Coffee represented the consolidation of an oligarchy and a middle class, now in decline, as well as the initial possibility of connecting the country, in a more stable way, with the international market.

Since then, there has been a growth in the number of farms dedicated to this workforce, combining small, medium and large-sized properties, opening up the possibilities for a better distribution of wealth.

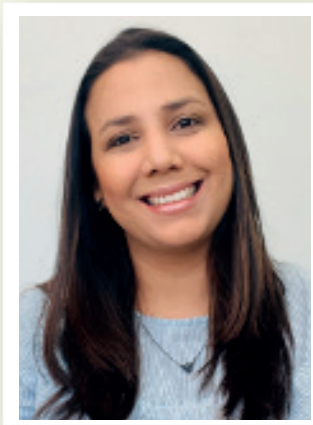
Like all agricultural production, the growth of the coffee sector involved the reduction of forest cover. However, unlike other types of plantations, coffee is usually grown combining shaded areas, which, in comparison, allows the presence of greater biodiversity, including tree species, shrubs, small mammals, birds and insects, including pollinating species.

However, in recent years, a series of factors, have been causing a change in land use, transforming coffee farms into other types of crops that are less friendly to the environment or replacing them with urban development projects.

This project seeks to identify mechanisms and economic alternatives to avoid this change in land use and preserve these farms as mixed refuges of biodiversity and generation of economic wealth.



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**María Fernanda Arias Araya**

Master's Degree in Management of  
Development Projects

Researcher

Research and Transfer Area, UTN  
Guanacaste campus

<https://orcid.org/0000-0003-3315-819X>

## Challenges and Solutions in Integrated Wastewater Management on Dairy Farms

The agricultural sector in Costa Rica is one of the activities that consume a significant amount of water resources (around 21%), and dairy systems are part of this consumption. Our nation's sanitation system faces significant obstacles, particularly in the agricultural sector, where a lack of technology and infrastructure restricts the population's access to commodities and services. The Causal Loop Diagram methodology aims to help farmers in the highlands of Guanacaste understand their situation and acquire the necessary skills to contribute to the sustainability of their farms and improve their quality of life. The Wastewater Sanitation Policy 2016-2045 supports water management in Costa Rica, emphasising the use of technologies that mimic natural processes.

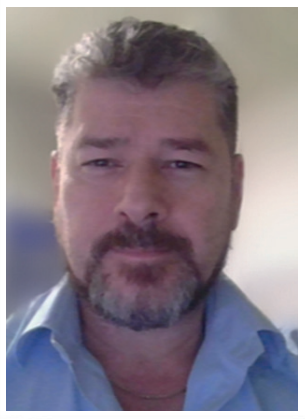
The Causal Loop Diagram technique simplifies the management of dairy farming wastewater, identifying feedback loops, stakeholder responsibilities, and assessing systemic changes, thereby enhancing water quality and ecosystem vulnerability.

Waste management involves collecting dry solids and using less water for cleaning pens. Non-food crops can use mature wastewater. In order to shift perceptions and guarantee the sector's survival, cooperation with producers, education, and awareness-raising are essential.

The circular economy can be supported by increasing the limited producer capacity in wastewater treatment through technical assistance, public-private partnerships, environmental awareness, and easily accessible technologies.



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### **Maynor Alberto Vargas Vargas**

PhD in Agricultural Sciences (Biochemistry and Applied Biosciences)

Coordinator of the Research Laboratories Management System

Vice Rector for Research and Transfer, UTN

<https://orcid.org/0000-0002-2264-7417>

## **Sustainable Ecotourism in Bajo La Paz: Balancing Conservation and Community Development**

The ecotourism Project in Bajo La Paz focuses on developing sustainable tourism that preserves biodiversity while fostering economic opportunities for the local community. Situated at the cloud forest in Piedades Norte, San Ramón, Costa Rica, this village of approximately 9,000 residents boasts a rich array of flora and fauna, making it ideal for responsible ecotourism.

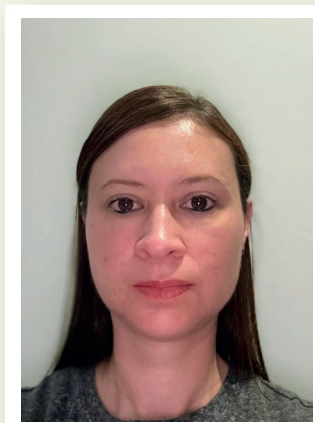
This Project emphasizes eco-friendly activities such as birdwatching, guided tours of the La Paz River and its scenic waterfalls, and visits to cultural landmarks like the traditional trapiche. These initiatives attract environmentally conscious tourists while creating income opportunities for locals. Key stakeholders, including hotel and restaurant owners, farmers, rural associations, and landowners, actively participate through training programs to promote sustainable tourism practices.

To mitigate risks such as environmental degradation and overcrowding, the experience employed systems-thinking tools like causal loop diagrams to analyze the relationships between tourism activities, environmental impact, and socio-economic factors. Strategies include environmental education and visitor management policies to protect natural resources. Partnerships with national and international organizations provide support for capacity building and funding, ensuring the long-term viability of the initiative.

The Bajo La Paz ecotourism project aspires to serve as a model for sustainable tourism, balancing conservation and economic development to demonstrate how rural communities can thrive while preserving their natural environment.



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**Gabriela Montes de Oca Vásquez**  
 PhD Natural Science for Development  
 Director  
 Center for Sustainable Development  
 Studies, UTN  
<https://orcid.org/0000-0003-2012-816X>



**Melissa Camacho Elizondo**  
 Master's Degree in Industrial Chemistry  
 Researcher  
 Center for Sustainable Development  
 Studies (CEDS)  
<https://orcid.org/0000-0003-3553-9041>

## Driving the Growth of Bio and Nano-pesticides as Eco-Friendly Agricultural Alternatives

Agriculture in Costa Rica faces significant challenges in pest management, particularly in crops of high importance such as bananas, pineapples and vegetables, which are critical for their production levels, export value, and pesticide usage. To address these challenges, advancements in bio and nanopesticides, including biological organisms and nanomaterials, have emerged as promising alternatives. These innovative technologies enhance pest control strategies while aligning with global demands for environmentally sustainable agricultural practices.

Therefore, the objective of this study was to analyze some perspectives of stakeholders, including academia, government, and industry, on the use of bio and nanopesticides in Costa Rican crops by creating a causal loop diagram. With the results of the CLD developed, we determined that the demand from both consumers and producers stands out as the most influential factors in the adoption of bio and nanopesticides. Also, regulatory policies are crucial supporting factors for creating a framework and the resistance to change from conventional to sustainable technologies is an impeding factor that was present in all the interviews. Therefore, it is important to interview additional stakeholders to ensure they are statistically representative of different sectors and conduct group interviews to obtain a group perspective.



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### **Melissa Montero Alvarado**

Master of Science in Education with  
Emphasis on Curriculum  
Professional Technician, Career  
Management  
CFPTE-UTN, Costa Rica  
<https://orcid.org/0009-0006-5186-1988>

## **AquaEcosystem**

Climate change is causing problems all over the world. Some governments support storm drainage systems but it seems that it is not enough due to lack of awareness and poor urban planning. For that reason, I think each person must have looked for options to help herself and others.

It is not very common to see rainwater-harvesting systems in homes. Generally, local governments are responsible for ensuring that a sewerage system is in place. But in this case, it does not happen and there are people directly or indirectly affected by rainwater.

This is the situation in some neighborhoods of Palmares Costa Rica, specifically in Calle Vargas, where I currently reside. At the time, there was only one house around and we built our house in a practically empty neighborhood.

Right now, there are many houses around and only for some of them are sewerage systems to collect rainwater. My house doesn't have the system and for that reason I want to create a self-sustainable space, my own AquaEcosystem.

AquaEcosystem consists of some ideas that can help to collect rainwater and be used in a pool, a well fish, to water trees or to store water. The principal idea is having a system that can avoid the floods or other similar, collect and use water rain.

Although it is a solution that I have thought of for my house, I feel that it can be a help for others as well and there may be several interested parties in the subject such as municipalities and ASADAS.

I have a sustainable home certification from the Ecological Blue Flag Program, and I want to work a bit from home.



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**Sergio Arturo Cubero Mata**

Master's in Educational Technology  
Academic producer  
Educational Technology Department -  
CFPTE

<https://orcid.org/0000-0002-9285-637X>

## Exploratory Use of Artificial Intelligence to Create a Systemic View of the Gold Mining Situation in Crucitas, Costa Rica, based on an Interview with President Chaves

The researcher must collect sources of information and select appropriate stakeholders. Currently, AI cannot conduct mind-mapping interviews, but it can process semantic information obtained during such interviews to identify causal relationships, especially when preparing to detect key variables from a theoretical list.

AI tools related to programming code libraries for data analysis - such as NumPy and Pandas - can significantly improve information processing. Once the final data set is prepared, visualization is improved using tools such as Matplotlib, Mental Modeler and Kumu.io.

In the case of the system density calculation, the data was analyzed directly using the data analysis capabilities of ChatGPT in Python, as well as in Mental Modeler, obtaining similar results. It is recommended that, when feasible, a research project employing the mind mapping methodology include an expert in AI and data analysis to validate the results of the inferences made by the AI linguistic models. This is essential, as the underlying AI actions involve programming and interpreting data analysis code libraries, such as Python coding in this case.

The method applied to build Mr. Chaves' perspective on the issue could be extended to other stakeholders to gain a broader understanding. However, analysis of the data from the President's speech highlights that the current government plans to extract gold from Crucitas, but lacks a clear strategy for doing so. Visualization of the data indicates that increased security in the Crucitas area would significantly affect other variables, such as future public income and the reduction of current environmental damage.

It is suggested that communication materials be created to increase social awareness and public debate about the Crucitas situation and related projects within UTN. These materials would help inform the public and encourage a deeper dialogue.



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**Silvia Ramírez Flores**

Master's Degree in Science and  
Technology for Sustainability  
Researcher

Investigation, UTN Pacific campus

<https://orcid.org/0000-0002-4809-8022>

## Evaluation of the Strategic plan for aquaculture in Costa Rica 2024-2029

In Costa Rica, a plan for development of aquaculture was created, this plan aimed at promoting the growth of this productive activity, necessary to provide protein to the population. This plan was last updated in 2023, and the positive and negative effects generated by the actions proposed in this plan remain unknown. On the other hand, the proposals for improvement made in this type of documents, are not adapt to the reality of the people who work in the activity, which has resulted in no significant changes being observed, and the production has not reflected an increase or improvement in social, environmental and economic terms. The purpose of this project is to evaluate the perception of the people involved in the fulfillment of the previous strategic plan, and based on the pending actions, together with the producers, generate a new group of actions based on the commitments that they are willing to assume and fulfill.

For this, participatory strategies such as causal diagrams will be used, first they will be built from the present problems based on everything that was not accomplished, and in a second moment we will work with aquaculture producers, academia and institutions with diagrams based on visions. to determine where aquaculture is seen in five years based on the installed capacities of all the actors involved. With this results it is expected a better comprehension of the activities and the people involved in it, in order to create a more adequate plan for developing this activity.



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**Mauren Rodríguez Castro**

Chemical engineer

Professor and researcher

Universidad Técnica Nacional, San Carlos campus

<https://orcid.org/0000-0002-1797-9732>



**Yesenia Marín Quesada**

Environmental management engineer

Researcher and coordinator of the

UTN's Water and Peace Biosphere Chair

Universidad Técnica Nacional, San Carlos campus

<https://orcid.org/0000-0003-1428-1993>

## Burning residual biomass in agriculture from agricultural crops

The burning of agricultural crop residues containing traces of agrochemicals is linked to the unintentional generation of persistent organic pollutants (POPs), known for their environmental persistence and toxicity. This project initially aims to identify the agricultural best practices implemented to prevent biomass burning in crops such as pineapple, sugarcane, and rice. Although Costa Rica has a legal framework for granting burning permits, illegal burning continues, attributed to bureaucratic barriers and insufficient oversight by the Ministry of Agriculture and Livestock (MAG). Furthermore, there is currently no quantitative data on the POPs generated during these activities.

The analysis seeks to understand the different perspectives on biomass burning, the limitations in the permit application process, interests in adopting more sustainable alternatives, and associated challenges. The results will serve as key inputs to support the achievement of the National Plan's goals, within the framework of the project "Strengthening National Capacities for Persistent Organic Pollutants (POPs) Management in Costa Rica, 2024–2028."



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## Epilogue

The approach and design of a virtual course aimed at academics of the Universidad Técnica Nacional (UTN) of Costa Rica to strengthen their research and teaching capacities began on October 31, 2023 at the campus of the University of Osnabrück (UOS), State of Lower Saxony in Germany, within the framework of the conference “Insights into biodiversity management in Germany and comparison with Costa Rica”. In this space, the design team composed of Costa Rican and German academics jointly established the topics, format, methodologies, dates of execution, among others.

From this joint work was born the online course “Applied transformative systems research for sustainable development”, which was conceived as a learning exchange activity, in which the trainees, through theory, the development of practical exercises and in most cases interviews with key actors, applied systems science methods for research and teaching with a strong participatory and interdisciplinary component.

Also during the course, the Costa Rican trainees were able to interact with UOS students, through working sessions and interviews on the approach to a problem or a vision applying systems science methods, which enhanced the exchange of learning on the course topics, but also different intercultural approaches.

The course evaluation provided for the development of a final research and teaching project where each trainee was able to apply the knowledge acquired to their own current or future topics of interest. The topics addressed included areas such as ecotourism and agroindustry of natural products in the town of Bajo La Paz in San Ramón, water resource management in the towns of Tilarán, Poás, Atenas and Alajuela, strategic planning for aquaculture in Costa Rica, management of research processes at UTN, urbanization of coffee-growing areas in the northern part of the canton of Alajuela, sustainable management of pineapple, sugar cane and rice biomass, generation Z and its vision of sustainability, production of bio-inputs in the highlands of Alajuela, artificial intelligence applied to national policy and perception of waste management in Paquera of Puntarenas.

The details of the projects and authors have been presented in this document and are evidence of the diversity of topics that each of the academics in their campus are developing. They also reflect lines of work and approaches that have been strengthened for several years in our university. Such is the case of those associated with water resources, especially those with a strong focus on the sanitation of urban and agricultural wastewater, as well as the sustainable management of watersheds, for the protection and regeneration of water bodies such as rivers, streams and springs. Another recurring theme is the Bioeconomy, which is manifested through the study and search for alternatives to the burning of biomass from crops such as pineapple, sugar cane and rice, as well as the generation and use of bioinputs such as bionanopesticides in the cultivation of coffee, and proposals for the sustainable industrialization of natural products in rural areas.

Always in relation to the projects, in days prior to the face-to-face presentation the UOS facilitator, Dr. Johannes Halbe, associate professor at the Institute of Geography and the Institute for Research in Environmental Systems (IUSF), both belonging to the UOS, was able to visit some of the sites where these initiatives are currently being developed or will be developed, among them:

- Dairy farm of producer Xinia Alvarado Soto, in El Silencio de Tilarán, Guanacaste province. The farm uses the wastewater from washing the corrals to produce biogas and the excrement to produce organic fertilizer with earthworms. It uses the biogas to prepare yogurt, custard, and sweets made from goat's milk.
- Fertinyc Company in Pital, canton of San Carlos, Alajuela province, to learn about the pineapple production and packaging process, but above all to learn about biological pest control techniques using specific strains of fungi and bacteria for this purpose, which reduces the use of agrochemicals.
- Nicoverde Company, also located in Pital, which focused on initiatives for the production of oyster mushrooms on pineapple stubble and the use of natural and bioactive extracts of sachu inchi seed, turmeric,

ginger, avocado and pepper for the production of cosmetics and food supplements, which is being developed in conjunction with the UTN campus in San Carlos.

- In the Bajo la Paz community of Piedades Norte de San Ramón, province of Alajuela, visits were made to cultural, historical and natural sites in the area, including typical restaurants, the monument to former president Francisco Orlich and the area around the La Paz river, which provides water to the Alajuela cantons of Palmares and San Ramón. A visit to the home of a local family was also organized to exchange ideas about the way of life in the area, and the most sustainable development options, especially prioritizing environmental issues.
- Community Water Service Operator (ASADA) Árbol de Guaria, in the central district of Alajuela, to learn about projects to protect the spring that provides them with drinking water, as well as other initiatives related to reforestation and protection of urban biodiversity, giving as an example the case of solitary bees, which are important pollinators. In these activities, the support of the students of the UTN Central Campus was highlighted through the volunteer programs and university community work (TCU) that it develops.
- Other activities of a more academic nature were a specific meeting with Mr. Luis Ricardo Sánchez, UTN Vice Rector for Teaching and Acting Vice Rector for Research and Transfer at that time. There were also exchanges with students from the Water Resource Management Engineering program at the Central Campus and with the team of researchers from the UTN's Center for Sustainable Development Studies (CEDS).

Among the lessons learned in this course that are worth highlighting are the exercise of a way of thinking that prioritizes the systemic approach, as opposed to linear thinking. In addition to this, promoting systems thinking more focused on a desirable future vision, and less on the problem and its negative consequences, which generates less pessimistic perceptions both in the mind of the researcher and in the allies who participate in collective activities in the approach to a topic or research challenge. Finally, the introduction to the use of computer programs for the diagramming, modeling and simulation of the systems developed, facilitates the application of what has been learned in future teaching and research proposals.

As transversal learning generated during the organization and execution of this course, the importance of a basic and instrumental handling of the English language among UTN academics stands out, which makes possible the active participation and exchange of ideas with academics and students from other latitudes. It was also evident the existence of 16 academics from all UTN campuses, with curiosity, creativity, but above all with a desire to learn and share new knowledge and experiences associated with research, transfer and teaching. Hence the importance of our university to continue strengthening the processes of internalization and academic exchange with UOS and other academic organizations around the world.

With final reflection, two fundamental challenges arise for the UTN, the first one is to give continuity to courses, workshops and other actions to strengthen research capacities and the generation of experiences in external projects, as well as the consolidation of research groups and communities in topics aligned to the lines of interest and relevance of each campus of our university. With the successful execution of this course, firm steps have been taken towards meeting these challenges.

MSc. Andrés Araya Araya

Researcher

Center for Sustainable Development Studies (CEDS) - UTN

