



EVENT REPORT

# Green Adaptation Strategies for Water Security in the Central American Dry Corridor

Nicoya, Costa Rica, 26 March 2019

# EVENT REPORT

Workshop

## **Green adaptation strategies for water security in the Central American dry corridor**

### **Co-organized by:**

Mesoamerican Center of Sustainable Development of the Dry Tropics (CEMEDE) and the Water Resources Center for Central America and The Caribbean (HIDROCEC) of the National University of Costa Rica (UNA).

Research Group INOWAS at the Department of Hydrosociences of the Technische Universität Dresden (TUD), Germany

Nicoya, Costa Rica  
26 March 2019

## About this report

This document contains the report of the workshop entitled “Green adaptation strategies for water security in the Central American dry corridor” organized in Nicoya, Costa Rica, on 26 March 2019. The workshop represented the official kick-off meeting of the bilateral German - Costa Rican project “Facilitation of green adaptation techniques for reduction of seasonal water scarcity in Costa Rica”.

Photo cover: Brasilito beach in Guanacaste province of Costa Rica (Photo: Serena Caucci)

## Acknowledgement

The project is funded by the German Ministry of Education and Technology (BMBF) and the Ministry of Science, Technology and Telecommunications in Costa Rica (MICITT).



## Report compiled by

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## How to cite this report

Stefan, C.; Suárez, A.; Bautista, P.; Alfaro, C.; Caucci, S.; Junghanns, R.; Walther, M. (2019) Report of the Workshop “Green adaptation strategies for water security in the Central American dry corridor”, Nicoya, Costa Rica, 26 March 2019.

Dresden, November 2019

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# Welcome address

The Chorotega Regional Campus of the National University of Costa Rica serves as host for this important event named " Green adaptation strategies for water security in the Central American dry corridor ".

More than two and a half decades ago, the United Nations adopted 22 March as World Water Day in recognition of the importance of this resource for life. There's no life without water. We agree on this and the need for conservation, development and good use of water resources. When I was in elementary school, teachers considered the water as inexhaustible resource. Today we know that this is not the case and that we must be aware of the importance of its rational use. Our university, and our campuses in particular, has been working on this task. Teaching, research and transfer activities contribute to the generation of knowledge for the best use of this vital resource.

That is why today I am pleased to see the theme water at this seminar, where we will have a large panel of national and international experts on managed recharge of aquifers, global implications and water security in coastal areas, adaptation of global circulation models for temperature, runoff and precipitation in Central America, saltwater intrusion and its implications, impact of droughts and projections of climate change scenarios, water security methodologies and methodologies for water governance.

*La Sede Regional Chorotega de la Universidad Nacional de Costa Rica sirve de anfitriona para esta importante actividad denominada "Estrategias de adaptación verdes para la seguridad hídrica del corredor seco centroamericano".*

*Hace más de dos décadas y media se adoptó por parte de la ONU el 22 de marzo como el Día Mundial del Agua en reconocimiento a este recurso como el más importante para la vida. Sin agua no hay vida. Estamos de acuerdo en esto último y en la necesidad de la conservación, el desarrollo y el buen uso de los recursos hídricos. Cuando estudiaba en la escuela primaria los maestros incluían al agua dentro de los recursos inagotables. Hoy sabemos que esto no es así y que debemos hacer conciencia de la importancia de su uso racional. Nuestra universidad, y nuestra Sede en concreto, ha venido trabajando en esa tarea. Desde la docencia, la investigación y la extensión se aporta al conocimiento para el mejor aprovechamiento de este vital recurso.*

*Es por eso que hoy me complace ver la temática a este seminario, donde contaremos con un amplio panel de expertos, nacionales e internacionales sobre los siguientes temas: recarga gestionada de acuíferos, implicaciones mundiales y seguridad hídrica en zonas costeras, adaptación de modelos de circulación global de temperatura, escorrentía y precipitación para Centroamérica, intrusión salina y sus implicaciones, impacto de las sequías. Impacto de sequías y proyecciones de escenarios de cambio climático, metodologías de seguridad hídrica y metodologías para gobernanza del agua.*

**Víctor Julio Baltodano Zuñiga**, Dean  
Sede Regional Chorotega, National University of Costa Rica (UNA)

# Setting the stage

## General context of environmental management in Costa Rica

Costa Rica is a water-blessed country with abundant rainfalls oscillating annually between 1,300 and 7,500 mm. A full set of measures and policies made Costa Rica globally famous for the success of its environmental protection efforts. This ecological commitment ranked the country on top of Latin American and Caribbean countries on the protection of human health and ecosystems. In 2015, the country also achieved 99% of its energy generation from renewable sources, an important milestone in its plan to go carbon neutral by 2021. But this highly privileged status on environmental protection received serious challenges when regarded from the perspective of sustainable water management. One of the main issues of concern relates to the high rainfall seasonality in the North Pacific Region, which increases dramatically the pressure on available freshwater resources. While some issues are currently being addressed at national level, at regional level the country is facing increased pressure from pollution of surface water, from seasonal water scarcity (for example in the Pacific insular communities) and from saltwater intrusion in north-western coastal areas such as Guanacaste province, which are exposed to an increased urban development and concentrated tourism.



*During the dry season, the local communities living on the islands of the Nicoya peninsula are severely affected by freshwater scarcity (photo: CEMEDE)*

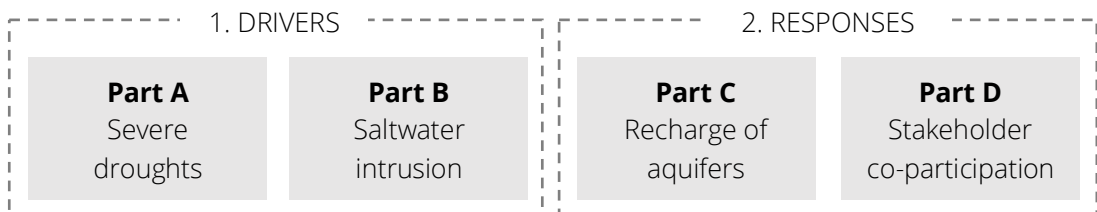
Moreover, the country's unique ecosystem is very vulnerable to changes in climate patterns, with shorter rainfall events and longer midsummer droughts expected to severely affect the replenishment of renewable water sources, so much needed for the country's vital ecosystem services such as hydropower generation and eco-agricultural production. To achieve a long-term resilience, Costa Rica needs a major swift in its common strategy of basically reacting to problems as they come along to a more precautionary approach for conservation and sustainable management.

# German – Costa Rican research collaboration on water resources management

To address these challenges, a new German – Costa Rican collaboration project entitled “Facilitation of green adaptation techniques for reduction of seasonal water scarcity in Costa Rica” was kicked-off in March 2019 with financial support from the German Federal Ministry of Education and Research (BMBF) and the Ministry of Science, Technology and Telecommunications in Costa Rica (MICIIT). On the Costa Rican side, the project is implemented by the Universidad Nacional Costa Rica (UNA) through its regional centres: the Water Resources Center for Central America and The Caribbean (HIDROCEC) and the Mesoamerican Center of Sustainable Development of the Dry Tropics (CEMEDE). The objectives of the 30-month collaboration project are to understand Costa Rica’s water-related challenges in vulnerable communities and to identify and test adaptation options for coping with water scarcity.

## Project kick-off workshop

To kick-off the project, UNA and TUD jointly organised an international workshop that took place at the CEMEDE main campus in Nicoya, Costa Rica, on 26 March 2019. The aim of the workshop was to promote a space for information and discussion on green adaptation strategies for water security in the Central American dry corridor, with emphasis on Costa Rica’s Guanacaste region, and exchange experiences on adaptation and intervention strategies at international level. The workshop included four parts divided in two blocks: 1) Drivers leading to water scarcity; and 2) Technical and non-technical interventions.



Workshop structure and main sessions



Group photo with the participants of the workshop “Green adaptation strategies for water security in the Central American dry corridor” organised by researchers from Universidad Nacional Costa Rica and Technische Universität Dresden, Germany, in Nicoya, Guanacaste peninsula, on 26 March 2019 (photo: CEMEDE).



# Introduction

The workshop was opened by Dr. Andrea Suárez Serrano with a brief introduction to water-related challenges in Guanacaste, Costa Rica, followed by the presentation of two complementary research projects that were used as basis for the present workshop.

INVITED SPEAKER:

**ANDREA SUÁREZ SERRANO** | Water Resources Center for Central America and The Caribbean (HIDROCEC-UNA), Costa Rica

Presentation of projects:

- Facilitation of green adaptation techniques for the reduction of seasonal water scarcity in Costa Rica (GREAT)
- Capacity for dialogue and co-construction of rural territorial development policies (CADICO-DTR)

MODERATOR:

**CAROLINA ALFARO CHINCHILLA** | School of Chemistry, National University of Costa Rica (UNA)

# **Presentation of projects: Facilitation of green adaptation techniques for the reduction of seasonal water scarcity in Costa Rica (GREAT) and Capacity for dialogue and co-construction of rural territorial development policies (CADICO-DTR)**

ANDREA SUÁREZ SERRANO

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*Dr. Andrea Suárez Serrano (UNA, Costa Rica) opens the workshop by introducing two projects and their contribution to the mitigation of climate change effects in the Guanacaste province of Costa Rica*

In her introductory talk, Dr. Andrea Suárez Serrani presented the main objectives of the project “Facilitation of green adaptation techniques for the reduction of seasonal water scarcity in Costa Rica (GREAT)”. The project aims to understand Costa Rica’s water-related challenges in vulnerable communities, to identify and test adaptation options for coping with water scarcity. Specifically, the project will focus on two case studies: i) Coastal aquifers salinization in the Santa Cruz Canton; and ii) Water scarcity in Pacific insular communities. We will focus on understanding the biophysical and socio-economical dynamics of both case studies to then test and assess the feasibility for implementing robust adaptation measures. In both cases this will involve strengthening cooperation between German and Costa Rican stakeholders; gaining insights about the water scarcity drivers through literature reviews, and collecting available hydrological data; estimate water use and determine water availability seasonality; and identifying suitable green adaptation measures based on ecosystem dynamics, e.g. building infrastructure for increasing rainfall water recharge. We highlight that beyond the importance of expanding the scientific knowledge about the drivers of both case studies, this proposal intends to develop strategic green approaches for contributing to water risk reduction in communities with severe constraints for achieving water security.

# Climate change

The changes in climate patterns became obvious over the past decade and the impacts on different aspects of the society are multifold. Researchers from the University of Costa Rica discuss the mechanisms that cause droughts in the Central American Dry Corridor and the implications of climate variability on regional aridity and water scarcity.

INVITED SPEAKERS:

**HUGO HIDALGO LEÓN** | Centre for Geophysical Research, University of Costa Rica (CIGEFI-UCR), Costa Rica  
Research results related to aridity and drought in the Central American Dry Corridor

**ERIC JOSÉ ALFARO MARTÍNEZ** | Centre for Geophysical Research, University of Costa Rica (CIGEFI-UCR), Costa Rica  
Climate scenarios and impacts of droughts and other hydrometeorological events in the Central American Dry Corridor

# Research results related to aridity and drought in the Central American Dry Corridor

HUGO HIDALGO LEÓN

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Severe and sustained droughts are part of the natural variability of the Central American Dry Corridor and Guanacaste. It is important to emphasize that although trends in precipitation in the sub-region in general are not significant, trends in temperature in recent years have caused increases in the aridity of the region. It should be noted that the spatial variability of aridity is high from year to year. The conditions that cause droughts in the Dry Corridor are warming and low pressure in the Tropical Pacific along with high pressure and cooling in the Caribbean. In this presentation, the authors analyzed the mechanisms responsible for a significant fraction of climate variability in the Central American Dry Corridor. Their results indicated that El Niño Southern Oscillation is not the only process that influences the climate of the Central American Dry Corridor, but that also the Caribbean Low Level Jet (representing the Trade Winds) is an important characteristic of the aridity and recurrence of droughts in this sub-region. The authors also discovered that severe and sustained droughts in the Corridor have a periodicity of about 10 years. The low-frequency process that may be related to these decadal variations is a low-frequency version of the Caribbean Low Level Jet.

# Climate scenarios and impacts of droughts and other hydrometeorological events in the Central American Dry Corridor

ERIC JOSÉ ALFARO MARTÍNEZ and PAULA MARCELA PÉREZ BRICEÑO

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*Dr. Eric José Alfaro Martínez and Ms. Paula Marcela Pérez Briceño (UCR, Costa Rica) explain the climate scenarios and the impacts of droughts and other hydrometeorological events in the Central American Dry Corridor*

Predicting rainfall during April-May-June (AMJ), as the first peak of the rainy season in the Central American isthmus, is very important since it has been observed that more or less humid conditions during AMJ tend to be preceded by early or late starts of the rainy season. A late onset of rainfall, for example, followed by drier than normal conditions during MJ and by a subsequent period of intense summer or heatwave, can significantly affect key socioeconomic sectors in the isthmus such as hydropower generation, drinking water supply or agriculture. In this presentation, data from 162 rainfall stations were used to construct predictive models for MJ as the first peak of the rainy season, using Canonical Correlation Analysis (CCA). The aspects to predict during MJ are rainfall accumulation and the Normalized Precipitation Index (NPI) in Central America. The sea surface temperature (SST) anomalies observed in the  $63^{\circ}\text{N} - 10^{\circ}\text{S}$  and  $152^{\circ}\text{E} - 15^{\circ}\text{W}$  domain were used as predictors. The CCA models, using the SST anomalies in February, show a good predictive ability of the accumulations and the NPI during MJ, in an important region of Central America. The results showed that warmer (cold) conditions in the eastern equatorial Pacific SST anomalies, along with colder (warmer) conditions in the North Tropical Atlantic during February, tend to be correlated with drier (wet) periods during the next MJ bimester in virtually the entire isthmus. This suggests that the SST could modulate rainfall during MJ in Central America by influencing the position of the Inter-Tropical Convergence Zone and the magnitude of trade winds.

# Saltwater intrusion

Saltwater from the ocean intrudes coastal aquifers and affects the water quality in the production wells that are close to the coast. This can further increase due to sea level rise and increased water demand pumping. As consequence: a) production wells are abandoned and new wells are drilled further inland, b) pumping rates are reduced (even to zero) during the peak dry season or saline water is pumped in the distribution network. This session gives an overview on saltwater intrusion cases in Costa Rica and provides examples on how modeling can help in the management of affected water supply systems.

INVITED SPEAKERS:

**ROBERTO RAMÍREZ CHAVARRÍA** | National Service for Groundwater, Irrigation and Drainage (SENARA), Costa Rica  
Case studies of saltwater intrusion in Costa Rica

**MARC WALTHER** | Technische Universität Dresden (TUD), Germany  
Is seawater intrusion by over-extraction of groundwater even worse than we expected?

## Case studies of saltwater intrusion in Costa Rica

ROBERTO RAMÍREZ CHAVARRÍA

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*Dr. Roberto Ramírez Chavarría (SENARA, Costa Rica) explains the mechanisms of saltwater intrusion in coastal aquifers and gives several examples of affected aquifers in Costa Rica*

Intrusion of saltwater into coastal aquifers occurs in many countries worldwide. The aquifers' salinization is a natural process but it can be accentuated by modifications of the natural conditions and changes in the freshwater-saltwater balance. Various cases of saltwater intrusion are observed in Nicoya peninsula. In a study from 2001, 15 out of 24 wells analyzed were affected by salinization and measures were proposed for the protection of vulnerable aquifers. Based on monitoring activities, SENARA mapped the aquifers and ranked them by priority for investigations, with Nosara, Cabuya and Puntarenas being assigned the highest priority in 2010. Dr. Ramírez gave some further examples of salinization (including data on groundwater quality) of the aquifers located close to places such as Playas del Coco, Playa Panama, Playa Potrero, Playa Brasilito etc.

Dr. Ramírez reiterated SENARA's commitment to investigate, protect and promote the use of groundwater resources in the country, as well as to coordinate the research activities on hydrological and hydrogeological characterization of Costa Rica's aquifers. To achieve these goals, SENARA makes use of adequate tools for territorial planning, aiming to guarantee sustainable management and to minimize impacts to the groundwater resources in the country.

## Is seawater intrusion by over-extraction of groundwater even worse than we expected?

MARC WALTHER

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*Dr. Marc Walther (TUD, Germany) demonstrates how saltwater intrusion can be assessed using numerical models and gives an example of groundwater modelling of a coastal aquifer in Oman*

Saltwater intrusion is a world-wide problem in coastal areas, where groundwater is used in a way that pumping rates exceed natural recharge. In most cases, groundwater is required foremost for irrigation, but also for industrial or household purposes, as surface water bodies are not continuously available throughout the year. Uncontrolled abstraction through unofficial pumps elevates the problem as communities cannot manage the water resources in a sustainable way and finally, groundwater wells are salinized rendering the water unusable. This often calls for costly water redistribution through aqueducts or water trucks. Although many research and applied investigations have been carried out to understand saltwater intrusion in many parts of the world, the transience of this phenomenon is mostly ignored. Few studies have shown, however, that a long-term management is crucial for a sustainable water availability, especially to keep marine saltwater intrusion at a respectable level. Managed aquifer recharge, in centralized or decentralized ways, has a strong potential to provide additional water resources through storing excess water, which is otherwise lost to the ocean, in the subsurface. This water can be used in dry seasons, and moreover, help to combat saltwater intrusion through the concept of positive hydraulic barriers. It is a current subject of science to provide a profound system understanding of positive (or mixed) hydraulic barriers.



# Groundwater recharge

Managed aquifer recharge (MAR) is used in several countries worldwide to enhance the natural recharge of groundwater systems. Successful examples demonstrate the efficiency of the approach in arid regions characterized by low precipitations but also in areas with heterogeneous spatial and temporal distribution of water resources. In this session, German and Costa Rican speakers reflect on the advantages of the technique and its contribution to the sustainable management of water resources, and discuss the opportunities for MAR implementation in Costa Rican context.

INVITED SPEAKERS:

**CATALIN STEFAN** | Technische Universität Dresden (TUD), Germany  
Managed aquifer recharge (MAR) as a tool for sustainable groundwater management

**JOSÈ PABLO BONILLA VALVERDE** | Instituto Costarricense de Acueductos y Alcantarillados (AyA), Costa Rica  
Opportunities for managed aquifer recharge in Costa Rica

# Managed aquifer recharge (MAR) as a tool for sustainable groundwater management

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*Dr. Catalin Stefan (TUD, Germany) introduces the concept of managed aquifer recharge as tool for sustainable groundwater management and presents experiences and lessons learned from international projects*

Strong precipitations are falling in Guanacaste but in only few months per year. In the rest of the time, the region suffers from draughts, leading the severe water insecurity and saltwater intrusion in the coastal aquifers. In his presentation, Dr. Stefan reflected on the potential retention of excess runoff during the raining season and temporal storage in the subsurface for later use in the dry season. The technique is known as managed aquifer recharge (MAR) and implies the intentional, monitored recharge of aquifers for subsequent use in drinking water supply, agriculture, or environmental benefits. MAR has several advantages over conventional water storage in dams and reservoirs: it requires much less land area, it can be implemented within the urban area, has lower capital costs and significantly reduces the evaporation losses. Depending on local hydrogeological conditions, water can be infiltrated using small ponds and basins or other subsurface constructions such as wells, trenches etc. To note that MAR is not meant as an exclusive technical solution but rather as an approach that can be combined or integrated in the available water infrastructure. Thus, MAR can offer excellent opportunities to capture and store the effluent of constructed wetlands, wastewater treatment plants, safeguarding the removal of viruses, pathogens and organic matter. In periods of heavy rainfalls, excess water can be quickly diverted to highly-permeable structures and allowed to infiltrate safely into the ground. Several examples from all over the world prove the efficiency of subsurface water storage, which may represent a sustainable solution for water management in the dry region of Guanacaste, Costa Rica.

# Opportunities for managed aquifer recharge in Costa Rica

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*Dr. José Pablo Bonilla Valverde (AyA, Costa Rica) presents different oportunities for implementation of managed aquifer recharge in Costa Rica*

In his talk, Dr. Bonilla introduced the opportunities for implementation of managed aquifer recharge in Costa Rica. The country benefits of abundant precipitations but they are not uniformly distributed in time and space. This leads to severe droughts in Guanacaste while other parts of the county are affected by floods. The presentation focused on two objectives: a) identification of suitable areas for MAR in Costa Rica, and b) evaluate the feasibility of a potential MAR project at a regional level. The study on mapping the suitability for MAR was conducted using a combined approach involving GIS-based multi-criteria decision analysis. Several thematic criteria were analyzed, such as the hydrogeological aptitude, terrain slope, drainage density and soil texture. After standardization, a simplified map algebra was used to compile a country-wide map that shows areas that are more promising and where further detailed studies are needed (see the following article for more details: <https://doi.org/10.3390/w8090391>). Further, a modified approach was used to assess the implementation of MAR in the Machuca river basin. Several aspects were discussed, such as the characterization of water demand in the region, the identification of a suitable water source, the existence of a proper aquifer, the availability of sufficient space to capture and treat the water to be infiltrated, and last but not least the technical capacities necessary to design, construct and operate such as project in the region. In near future, the approach can be adopted in Costa Rica to overcome temporary water shortage at the end of the dry season, to prevent saltwater intrusion in coastal aquifers and as an alternative source for water supply systems.

# Governance

A significant amount of research on sustainable development is currently done but most outcomes are not easily available to local actors. Several approaches are proposed and discussed in order to increase the societal uptake of research results. These included the mapping of stakeholders and their interests, proposing co-participation and active involvement of stakeholders at different research stages, and promoting the dialogue between the academics and policy makers.

INVITED SPEAKERS:

**FERNANDO SÁENZ SEGURA** | International Centre of Economic Politics for the Sustainable Development (CINPE-UNA), Costa Rica  
Capacity for dialogue and co-construction of rural territorial development policies (CADICO-DTR)

**SERENA CAUCCI** | Institute for Integrated Management of Material Fluxes and of Resources, United Nations University, Germany  
Transdisciplinary approach to complex water-related management: stakeholder assessment and analysis for Costa Rica

# Capacity for dialogue and co-construction of rural territorial development policies (CADICO-DTR)

FERNANDO SÁENZ SEGURA

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*Dr. Fernando Sáenz Segura (UNA, Costa Rica) talked about developing capacity for dialogue and policies for rural territorial development*

The abstentionism from the recent electoral contest demonstrates the low effectiveness of development policies in areas not adjacent to the Central Valley. This situation is taken advantage of by political parties to impose a biased agenda that does not take into account scientific-technical evidence for decision making. Representatives of these provinces point out that the regional context is not considered to develop effective development policies. The regional governance bodies express the need to identify contextualized policies for Rural Territorial Development (DTR). However, the local actors have limitations to access and understand relevant information on global changes that affect the DTR. The presentation focused on the: strengthening the capacities of stakeholders in the Chorotega Region to construct, discuss, propose and implement DTR policies contextualized to the regional reality and adapted to global changes. Working collaboratively with communities, governance bodies such as Territorial Development Councils and civil organizations, the project CADICO-DTR proposes: i) Facilitating access and interpretation of scientific-technical information on global changes to relevant actors and spaces of articulation and regional governance. ii) Promoting a space for dialogue between academics and local actors that allows for the construction of contextualized Rural Territorial Development policies for the Chorotega Region. iii) Identifying mechanisms that allow for placing on the agenda the needs and contextualized policies constructed for the Chorotega region. The expected results include a better capacity for dialogue, planning, support, and advocacy of the Chorotega region in the definition of its DTR policies.

# Transdisciplinary approach to complex water-related management: stakeholder assessment and analysis for Costa Rica

SERENA CAUCCI

Institute for Integrated Management of Material Fluxes and of Resources, United Nations University, Germany  
email: caucci@unu.edu



*Dr. Serena Caucci (UNU-FLORES, Germany) introduced a transdisciplinary approach for stakeholder assessment and analysis*

Small to medium sized cities are the fastest growing human settlements in Latin America for the next decades. Despite the abundance of water resources, climate projections are not sparing the countries from start thinking of resilience approaches that would avoid extreme droughts in the dry season. An intensive inclusion of stakeholders and social aspects in infrastructure planning and design becomes essential. Co-participatory approaches have lately received attention because participation can help identify integrated and acceptable solutions on the ground and allow the implementation of sustainable water management resources. The design of the participatory processes is essential because it has to assure the correct mix of actors, degrees of participation, and process-steps have to be identified in the planning phase of the project. An assessment and design of multi-scalar systems approach with social network analysis and bottom-up participative research could be a path to be undertaken by the policy makers. The design criteria refer to i) the type of actors involved, ii) the stage of the research process where these stakeholders are involved, iii) the degree of their involved, and iv) the methodology used for such an assessment. Workshop activities can be adapted to the specific context and needs, especially where the involved stakeholders meet conflicting interests since claiming the same limited resources (water) for different purposes. Efforts to understand the different perspectives of the actors involved is extremely crucial to find solutions that would not only addresses the economic, technical, and environmental aspects of the problem, but also its social acceptance.

# General discussion

The workshop was concluded with a plenary session with contributions from the participants. Opinions were expressed on challenges and opportunities for the implementation of managed aquifer recharge in Costa Rica, the legal aspects associated with the development and adaptation of aquifer management plans, as well as ideas on rising awareness and using communication as supporting instrument in the decision making process.

MODERATOR:

**PÁVEL BAUTISTA SOLÍS** | Mesoamerican Center of Sustainable Development of the Dry Tropics (CEMEDE-UNA), Costa Rica

# Challenges and opportunities for the implementation of managed aquifer recharge in Guanacaste

With contributions from representatives of National Institute of Learning (INA), Agricultural Technologies for Earth and Water Department, President of ASADA from Potrero Beach, Dirección de Aguas; HIDROCEC & CEMEDE, UNA.



Interest and willingness to support in the implementation of MAR technologies was shown by the participants, especially in the area of Nicoya and Potrero.

## CHALLENGES

- Concerns related to the legal aspects on how environmental law could be adopted MAR because so far MAR is not regulated in Costa Rica. MAR should be first embedded thus in the framework of integrated water management and considered as climate change mitigation strategy of vulnerable communities.
- The most common solution for aquifer salinization (coastal areas), in terms of water availability for users, is via transport of water from continental aquifers.

## OPPORTUNITIES

- HIDROCEC & CEMEDE offer full support for MAR investigation and development. The discussions focussed on the need to transfer academic knowledge to public institutions. Additional involvement of institution was requested by the Academy in the Water Day related challenges for the Chorotega region. From the University of HE students are willing to support MAR development projects and Master theses on MAR can be developed.
- A need of formal suggestion of MAR implementation to the Guanacaste Local Authorities was highlighted This could create MAR awareness at the institutional



level and potentially generate the willingness to support MAR implementation in the Dry Regions of Costa Rica.

## Legal aspects and aquifer management plans for MAR implementation

With contributions from: Ms. Grace Madrigal Barrantes (AyA), Mr. Roberto Ramírez Chavarría (SENARA).



- There is an urge to modify and update actual water legislation.
- Focus was placed more on sanctions for illegal wells and illegal water connections stressing the exploitation of aquifers (only in Guanacaste there are more than 3000 wells, legal and illegal).
- Concerns on the massive tourism development were shown. Better control on the tourism sector and related water pricing should be developed.
- Lack of legal basis for action to avoid water speculation. None of the functionaries have authority to access private property even if they know of an illegal perforation happening there.
- There is a lack of basin management plans. A revision of such plans seems mandatory according to the workshop participants.
- Need for further state investment (lack of proper budget) and articulation spaces for the development of the necessary policies.

## Awareness and scepticism on green solutions implementation

With contributions from: Hydrological Engineering (HE) students, Dr. José Pablo Bonilla Valverde (AyA), representative of Peninsula Papagayo (private tourism development), Dr. Catalin Stefan – CS (TUD) and Dr. Serena Caucci – SC (UNU-FLORES), Dr. Pavel Bautista Solis and Mr. Cristian Golcher (CEMEDE-UNA).



- There is questioning on which green technologies could specifically bring benefits for the local communities, as not all have the same effectiveness depending on the area of application.
- The private sector worries over the basin impact of implementing green technologies.
- CS: Green means following and learning from nature relating inquiries of Green being just a label.

### OVERCOMING THE BOTTLENECKS AND INCREASING AWARENESS

- Avoid misunderstanding related to green technologies and sustainable technologies. It is very important that all actors present start involving the actors who are missing (farmers, public institutions).
- Need of increase awareness of MAR among key stakeholders and local population. Clear understanding and benefits of green technologies and MAR builds acceptance.
- There is an urge to incorporate and prioritize citizen participation in water related issues and to work on modifying the social misconception over restoration possibilities regarding water bodies.

- Lack of representation from the agricultural sector in contemplating MAR for the discussion. MAR aspects should be co-addressed also in presence of the Ministry of Agriculture and agriculture practitioners.

## Communication as supporting instrument in decision making process

With contributions from representatives of: Dirección de Aguas, AyA.



- A bilateral lack of trust between citizens and water authorities was identified. The inefficient communication of water professionals with local communities (referencing the lack of community understanding on the relevant subjects as well as not giving the actors the proper motivation to generate love and passion for water-related topics).
- Illegal well perforation must continue to be unpunished. Currently, citizens are well aware that perforations without permit is cheaper than the one done with permit.
- No incentives for mindset changing due to elevated costs and beaurocracy for legal well perforation activities.
- It is estimated that approximately 2000 legal wells exist, and probably for every legal one there are ten illegal. There are seven functionaries of the Dirección de Aguas that attend to the entire Guanacaste and Puntarenas provinces, which do field work (before there was only one who started in 2012). Apparently, this is the main reason for so many illegal wells.

### ACTION TO BE TAKEN

- It is highlighted the importance of communication in terms of the public institutions. The lack of consensus delays all possible actions to be taken; primarily pursuing a change of water legislation.

# Closing address

The forum held in the Tempisque auditorium of the Nicoya Campus of the National University generates a rich experience to learn about alternatives for integrated water resource management. It is a priority at a time when climate variability maintains high levels of impact in the Mesoamerican Dry Tropic region, and the need to proactively address the water security of coastal and island communities in the province of Guanacaste, Costa Rica is demonstrated.

In Costa Rica, the province of Guanacaste is the area that has the driest conditions, however it maintains a dynamic growth of tourism and residential development. The foregoing generates pressures for access and availability of water, especially in the coastal strip that concentrates the majority of the country's tourist activity.

Thus, the meeting of national and international experts around the water issue generates greater confidence that we will know how to conduct scientific research that allows us to address the challenges that arise in the region with the generation of scientific knowledge.

For the Mesoamerican Center for the Development of the Dry Tropics (CEMEDE) it is a pleasure to have the accompaniment of prestigious institutions at national and international level. We especially thank the Technische Universität Dresden (TUD), Germany, through the support of the Department of Hydrosocieties and the INOWAS Research Group.

To all national participants who are also a strategic part of the challenges that are presented to us, including the Costa Rican Institute of Aqueducts and

*El foro llevado a cabo en el auditorio Tempisque del Campus Nicoya de la Universidad Nacional genera una rica experiencia para conocer alternativas de gestión integrada del recurso hídrico. Resulta prioritario en momentos en que la variabilidad climática mantiene altos niveles de afectación en la región del Trópico Seco Mesoamericano, y queda demostrada la necesidad de atender de manera proactiva la seguridad hídrica de las comunidades costeras e insulares de la provincia de Guanacaste, Costa Rica.*

*En Costa Rica, la provincia de Guanacaste es la zona que posee las condiciones más secas, sin embargo mantiene una dinámica de desarrollo turístico y residencial en crecimiento. Lo anterior genera presiones por el acceso y disponibilidad de agua, sobre todo en la franja costera que concentra la mayoría de la actividad turística del país.*

*Siendo así, el encuentro de expertos nacionales e internacionales alrededor del tema hídrico genera mayor confianza de que sabremos generar investigación científica que permita atender los desafíos que como región se presentan y se debe responder con la generación de conocimiento científico.*

*Para el Centro Mesoamericano de Desarrollo del Trópico Seco (CEMEDE) es grato contar con el acompañamiento de instituciones de prestigio a nivel nacional e internacional. De manera especial agradecemos a la Universidad Técnica de Dresde (TUD), Alemania, a través de acompañamiento de Departamento de Hidrociencias y de Grupo de Investigación INOWAS.*

*A todos los participantes nacionales que también forman parte estratégica en los retos que se nos presentan, entre ellos al*

Sewers (AyA), and the Center for Water Resources for Central America and the Caribbean (HIDROCEC), as well as researchers and administrative staff of the CEMEDE of the National University, Costa Rica: together we will know how to find the answers to improve the living conditions of the population and contribute in knowledge and innovation to future generations.

I am looking forward to welcome you in our next events and hope for more joint activities and support.

*Instituto Costarricense de Acueductos y Alcantarillados (AyA), y al Centro de Recursos Hídricos para Centroamérica y el Caribe (HIDROCEC) y a los investigadores y administrativos del CEMEDE de la Universidad Nacional, Costa Rica: entre todos sabremos encontrar las respuestas para mejorar las condiciones de vida de la población y aportar en conocimiento e innovación a las futuras generaciones.*

*Los esperamos en los próximos eventos y que siempre mantengamos las acciones de articulación y apoyo conjunto.*

Cordially / *Cordialmente,*

**Juan Carlos Picón Cruz**

Director, CEMEDE

Universidad Nacional, Costa Rica

# Follow-up activities

A series of activities undertaken after the joint workshop in Nicoya aimed at further promoting the workshop's activities and reaching out to a wider audience. This included the participation to the 5<sup>th</sup> Latin American Conference on Sanitation (LATINOSAN 2019), a lecture and a short training course at the University of Costa Rica for students and staff members of HYDROCEC, and meetings with various institutions in San José.

## Participation to the 5<sup>th</sup> Latin American Conference on Sanitation (LATINOSAN 2019)

The 5<sup>th</sup> LATINOSAN conference represents a platform for analyzing the social, economic and political changes occurring the Latin American and Caribbean (LAC) countries. The conference aims to promote agreements and commitments among LAC countries, which allow the reduction of gaps in sanitation and water supply services, ensuring universal and equitable access in collective and individual systems and making progress in achieving the SDGs. Dr. Stefan (TUD) and Dr. Caucci (UNU-FLORES) used this excellent opportunity for interacting with decision and policy makers from Costa Rica and other LAC countries and establish new contacts for potential joint activities in the future.

At the invitation of the Sub-Commission for Water and Sanitation of National Council of Rectors (Consejo Nacional de Rectores - CONARE), Dr. Stefan contributed with a short lecture on the benefits of managed aquifer recharge and gave some examples of successful applications worldwide. The presentation was included in the session dedicated to the sub-theme 4.6 "The role of green infrastructure as a basis for water, energy and food security in LAC". The session organizers are kindly acknowledged for supporting the conference registration costs, with special thanks conveyed to Dr. Caroline Alfaro Chinchilla from the School of Chemistry (UNA) for making the necessary arrangements.



*The discussions about the potential application of managed aquifer recharge solutions in Costa Rica continued during the LATINOSA conference. From left to right: Dr. Catalin Stefan (TUD, Germany), Ms. Grace Madrigal Barrantes (AyA, Costa Rica), M.Sc. Viviana Ramos Sánchez (AyA, Costa Rica), and Dr. Serena Caucci (UNU-FLORES, Germany)*

## Lecture on groundwater modeling and a short training course using the web-based INOWAS platform for students and members of staff of HIDROCEC-UNA

For better exemplification of the benefits of managed aquifer recharge and its role in sustainable water resources management, a short training course on groundwater modeling was provided for graduate students and members of staff of HIDROCEC-UNA. To set the stage for the course, it was necessary that all participants were at a similar level of understanding related to groundwater management. For this, JProf. Marc Walther (TUD) provided an introductory lecture on groundwater modeling and visualization. In his lecture, Marc explained why the subsurface, i.e. the porous media and water stored within, needs to be monitored for a reliable assessment of the status quo. The data obtained through monitoring can then be used for the setup of a groundwater model, which provides the possibility to run through different management scenarios. However, modelling results need to be interpreted as the models are only simplified, abstract representations of the real world. For this, visualizations of the modelling results need to be created. Such visualizations are the most important tool to carry the expert knowledge to the decision maker. Finally, visualizations, and thus modelling results, should show the possible outcome of management options, if not better also the inherent insecurity of modelling, which arises from the simplification of the real world.



*Ralf Junghanns (TUD, Germany) teaches students and staff members of HIDROCEC-UNA, Costa Rica, how to setup and run a numerical groundwater model using the free, web-based INOWAS modelling platform*

Following the introductory course, Ralf Junghanns (INOWAS, TUD) introduced the main principles of the web-based groundwater modelling platform INOWAS. The participants learned how to represent an abstracted version of the reality using a simplified conceptual model, then were guided through the sequential steps in the setup and calculation of the model using the INOWAS interface.

In continuation of the training course, Dr. Serena Caucci organised and led an interactive workshop on stakeholders' assessment for sustainable water management. The workshop was attended by graduate students and staff members of HIDROCEC-UNA.



*Dr. Serena Caucci (UNU-FLORES, Germany) interacts with the participants of a workshop on stakeholder assessment*

## **Meetings in San José with representatives of institutions responsible for water services and water management**

The first meeting took place at the Instituto Costarricense de Acueductos y Alcantarillados (AyA), where Dr. Stefan and Dr. Caucci met the representatives of Research and Development Department and the International Cooperation Department. During the meeting, the cooperation project between UNA, TUD and extended consortium was introduced to AyA representatives. All sides reiterated their strong interest in further collaboration, with emphasis on the topics previously identified by TUD and AyA. It has been recommended to continue the discussions through the initiation of a joint Committee for Technical Investigation, together with representatives of SENARA and DA-MINAE.



*Dr. Serena Caucci (UNU-FLORES, left) and Dr. Catalin Stefan (TUD, right), met Lic. Rodhe Baez, the representative of International Cooperation Department and M.Sc. German Gustavo Mora Rodriguez, the Director of the Research and Development Department of AyA*



The next meeting took place at the National Service for Groundwater, Irrigation and Drainage (in Spanish: *Servicio Nacional de Aguas Subterráneas, Riego y Avenamiento* – SENARA), where Dr. Stefan and Dr. Caucci met representatives of the Research and Water Management Units. In the very open atmosphere of the meeting, Dr. Stefan introduced the scope and objectives of the ongoing collaboration project between UNA and TUD, informed about the preliminary discussions with AyA and reiterated the need to establish a larger groundwater consortium. SENARA expressed interest in future collaborations and offered support in groundwater-relevant data sharing. Based on previous and existing monitoring data, SENARA suggested several aquifers as possible locations for future research projects on managed aquifer recharge. Further discussions are needed for concretisation of specific research objectives, depending also on availability of funds and the launch of the joint Committee for Technical Investigation.



*Dr. Serena Caucci (UNU-FLORES, left) and Dr. Catalin Stefan (TUD, right) met the representatives of National Service for Groundwater, Irrigation and Drainage (SENARA): Ms. Sonia Castro Chacón – Management Unit, Mr. Alonso Alfaro Martínez – Coordinator of Research Unit, Ms. Clara Luz Agudelo Arango – Coordinator of Water Management Unit, and Mr. Roberto Ramírez Chavarría – Director of Research and Water Management Unit of SENARA, Costa Rica*

## **Lecture for the students and members of staff of the School of Health Technologies at the University of Costa Rica**

Towards the end of the stay in San José, Dr. Stefan and Dr. Caucci were invited to give a lecture at the School of Health Technologies of the University of Costa Rica. The lectures were attended by students and members of staff who were introduced by Dr. Stefan to the general concept of managed aquifer recharge and its role in the hydrological cycle. Dr. Caucci's talk was on environmental sanitation, a very actual and relevant topic for the audience.



*Dr. Stefan giving a lecture on managed aquifer recharge for the students and members of staff of the School of Health Technologies at the University of Costa Rica*

## **Field trip to Brasilito on the north-western side of Guanacaste peninsula**

Brasilito is a small town in the Guanacaste province, known as budget location for tourists on the Pacific side of the country. The water supply to the inhabitants and local hotels is managed by the local ASADA, which operates three groundwater extraction wells. Due to very low precipitations falling during the dry season, the groundwater levels in the Brasilito area declined, which further led to increased intrusion of saline water into the underlying aquifer. The project team met the representatives of CEMEDE-UNA and ASADA Brasilito and discussed about the impact of saltwater intrusion on the local water supply system.



*The main groundwater well in Brasilito that is used to deliver drinking water at 5 l/s to the local community and touristic hotels in the town*

To overcome seasonal water deficit in Brasilito and surrounding communities, a major project is in development to construct a new aqueduct and a storage tank aimed at increasing the water availability for several communities of Guanacaste province.

# Annexes

**Annex 1** | Team of experts

**Annex 2** | Workshop agenda

**Annex 3** | Event photos

## Annex 1 | Team of experts

(in alphabetical order)



**ALFARO CHINCHILLA, Carolina**, M.Sc.

Researcher, Waste Management Laboratory (LAGEDE), National University of Costa Rica (UNA)

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Ms. Alfaro works at the School of Chemistry where she teaches various courses related to cleaner production and environmental chemistry. Her research work is oriented to demonstrate and improve alternative water sanitation systems, especially in the tropical conditions. She is interested in the transfer of technical and scientific knowledge that allows the appropriation of sanitation technologies by users in small communities.



**ALFARO MARTÍNEZ, Eric José**, PhD

Deputy Director, Centre for Geophysical Research (CIGEFI), University of Costa Rica (UCR)

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Dr. Alfaro is Full Professor at the School of Physics, University of Costa Rica, teaching since 1989. His interest areas include climatology, ocean-atmosphere interaction, meteorology, physical oceanography and multivariate statistical models. Dr. Alfaro has special interest in the statistical assessment of seasonal predictions from numerical model outputs, related also with climate change; and their comparison with the observed data in the Mesoamerican region.



**BALTODANO ZÚÑIGA, Victor Julio**, PhD

Dean, Chorotega Regional Headquarters, National University of Costa Rica (UNA)

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Dr. Baltodano has a M.Sc. in Business Administration and a Doctorate in Social Sciences. He is the Dean of the Chorotega Regional Headquarters, National University of Costa Rica (UNA).



**BAUTISTA SOLÍS, Pável**, PhD

Researcher, Mesoamerican Center of Sustainable Development of the Dry Tropics (CEMEDE), National University of Costa Rica (UNA)  
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Pável Bautista Solís is a Mexican agronomist specializing in rural development (Universidad Veracruzana, Mexico). He holds a master's degree in ecological agriculture with emphasis on land use planning (CATIE, Costa Rica); and a doctorate in tropical agroforestry sciences with emphasis on rural development (University of Bangor, United Kingdom). He has been working on research and technical cooperation projects in Central America for 18 years. His lines of research and practice include environmental livestock, agroecology, rural development, water governance and adaptation to climate change. He currently coordinates the PRO-RBA (FUNDER-UNA) and CADICO-DTR (FUNDER-UNA) projects; and is co-principal investigator of the GREAT project (BMBF-MICITT), all implemented in communities vulnerable to the impacts of climate change in the province of Guanacaste and Puntarenas, Costa Rica.



**BONILLA VALVERDE, José Pablo**, PhD

Engineer, Costa Rican Institute of Aqueducts and Sewers (AyA)  
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Dr. Bonilla did his doctoral research within the Research Group INOWAS of the Technische Universität Dresden, Germany, and received his PhD degree in 2018. He currently works as Director of the Functional Area of Risk Management at the Costa Rican Institute of Aqueducts and Sewers (AyA). He also teaches in the Environmental Health Career of the School of Health Technologies of the UCR. He still collaborates with the research group INOWAS.



**CAUCCI, Serena**, PhD

Researcher, Institute for Integrated Management of Material Fluxes and of Resources, United Nations University (UNU-FLORES)  
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Dr. Caucci is a Senior Research Associate in the Waste Management Unit at the United Nations University, Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES), Germany. She works on academic and capacity development activities in waste management aspects within the Water-Soil-Waste Nexus, supports the process of research product development, and contributes to the ongoing capacity development work related to co-participatory approach multi-stakeholder projects in water resource management.



**HIDALGO LEÓN, Hugo**, PhD

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Dr. Hidalgo currently works at the Departamento de Física Atmosférica, Oceánica y Planetaria, University of Costa Rica (UCR) and has over 20 years of experience in hydrology. His research interests are in meteorology, hydrology and climatology. He is the director of the Center for Geophysical Research (CIGEFI) and a member of the Costa Rican Academy of Sciences (ANC).



**JUNGHANNS, Ralf**, Dipl.-Ing.

Researcher, Research Group INOWAS,  
Technische Universität Dresden (TUD)  
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Mr. Junghanns works with the Research Group INOWAS at the Technische Universität Dresden (TUD) as full-stake software engineer and groundwater modeler. He is the main IT developer of the web-based INOWAS platform and is fluent in several programming languages.



**PÉREZ BRICEÑO, Paula Marcela**, M.Sc.

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Ms. Pérez Briceño has a Bachelor in Geography (2011) from the University of Costa Rica and a Master in Integrated Coastal Zone Management (2017). She is currently teaching in the field of Hydrological Engineering at the Chorotega Campus, National University, School of Geography (Rodrigo Facio Campus) and Environmental Health (Guanacaste Campus), University of Costa Rica. She is a researcher at the Center of Geophysical Investigations (CIGEFI-UCR), where she has conducted studies related to the impact of disasters before extreme hydrometeorological events in terms of risk management. She has several publications and has participated in national and international congresses.



**PICÓN CRUZ, Juan Carlos**, PhD

Director, Mesoamerican Center of Sustainable Development of the Dry Tropics (CEMEDE), National University of Costa Rica (UNA)  
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Dr. Picón Cruz received his PhD in Human and Sustainable Development from the Latin American Center for Development, Universidad Bolivariana de Chile (2015); a Master in Nature Tourism from the Universidad Nacional in Costa Rica and Bachelor in Business Administration from the Universidad Nacional in Costa Rica. He has 16 years of university academic experience, among which he has participated in 10 academic projects of Research, Extension and Academic Activities. He has participated as a speaker and lecturer in different national and international academic events related to tourism, environment and society. Since 2008 he belongs to the Latin American Network of Researchers in Development and Tourism (RELIDESTUR).



**RAMÍREZ CHAVARRÍA, Roberto**, PhD

Director, Research and Water Management Unit, National Service for Groundwater, Irrigation and Drainage (SENARA)  
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Dr. Ramírez Chavarría is a geologist and civil engineer and has a Master in Hydrogeology and Water Resources Management from the University of Costa Rica. He worked at SENARA for 22 years, currently as Director of the Directorate of Research and Water Management. Part of the work done in SENARA are calculations of water balances, potential or calculated by fluctuations in levels, hydrogeological studies in the Central Valley and Guanacaste. He participates in Technical Commissions related to groundwater contamination by hydrocarbons and arsenic, water balances, hydrogeological studies in prioritized aquifers, and in projects with the International Atomic Energy Agency (IAEA).



**SÁENZ SEGURA, Fernando**, PhD

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Dr. Sáenz holds a PhD in Development Economics from the University of Wageningen, in the Netherlands. He currently works as researcher at the International Centre of Economic Politics for the Sustainable Development of National University of Costa Rica (CINPE-UNA). His research interest is on agricultural and institutional economics, public policies and development of rural territories. He teaches various postgraduate courses.



**STEFAN, Catalin**, PhD

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Technische Universität Dresden (TUD)  
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Dr. Stefan is the Head of the Research Group INOWAS at the Department of Hydrosociences of the Technische Universität Dresden, Germany. Together with his team, Catalin strives to achieve his research goals through a multicultural, international perspective. The research foundation of his work is based on two pillars: understanding the processes occurring during managed aquifer recharge and development of web-based simulation software for groundwater modeling applications. Dr. Stefan is co-chair of Commission on Managed Aquifer Recharge of the International Association of Hydrogeologists (IAH).



**SUÁREZ SERRANO, Andrea**, PhD

General Coordinator, Water Resources Center for Central America and The Caribbean (HIDROCEC),  
National University of Costa Rica (UNA)  
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Dr. Suárez is the General Coordinator of the Water Resources Center for Central America and The Caribbean (HIDROCEC) at the Universidad Nacional Costa Rica (UNA). Dr. Suárez has a 17-year academic career, always linked to research projects on water resources. In addition, Suárez has stood out for her gifts of leadership and management of research projects and the development of the career in Hydrological Engineering at UNA. In addition, she is responsible for managing resources necessary to establish the laboratories of HIDROCEC and leading the work of this center of research to become a regional reference on management related studies integrated water resource. Dr. Suárez was the director of CEMEDE and HIDROCEC (2016-2018), where in addition to her administrative responsibilities she developed research on integrated watershed management, drinking water quality and water treatment.





**WALTHER, Marc**, PhD

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Dr. Walther is Junior-Professor of Contaminant Hydrology at the Department of Hydrosociences of Technische Universität Dresden, in joint appointment with the Helmholtz-Centre for Environmental Research (UFZ) Leipzig, Germany. His research interests include: water in (semi-)arid regions, groundwater quantity and quality in coastal areas, numerical modeling in the saturated and unsaturated zone, simulation of groundwater flow and transport processes, density driven and variable viscosity flow in porous media, parameterization, interpolation and mesh generation in concurrence with hydro-geological structuring.

## Annex 2 | Workshop agenda

**Date:** 26 March 2019. **Location:** CEMEDE-UNA, Sede Regional Chorotega

Time	Activity	Speaker
09:00-09:15	Welcome address	<b>Víctor Julio Baltodano Zuñiga</b> , PhD. Dean. Sede Regional Chorotega, UNA
09:15-09:45	Presentation of projects: Facilitation of green adaptation techniques for the reduction of seasonal water scarcity in Costa Rica (GREAT) and CADICO-DTR	<b>Andrea Suárez Serrano</b> , PhD. General Coordinator of HIDROCEC-UNA, Sede Regional Chorotega.
09:45-10:15	Managed aquifer recharge (MAR) as a tool for sustainable groundwater management	<b>Catalin Stefan</b> , PhD. Head of Research Group INOWAS, Department of Hydrosociences, Technische Universität Dresden
10:15-10:35	<i>Refreshments</i>	
10:35-11:05	Research results related to aridity and drought in the Central American Dry Corridor	<b>Hugo Hidalgo León</b> , PhD. Director of the Centre for Geophysical Research (CIGEFI), UCR.
11:05-11:45	Is seawater intrusion by over-extraction of groundwater even worse than we expected?	<b>Marc Walther</b> , PhD. Junior Professor of Contaminant Hydrology. Department of Hydrosociences, Technische Universität Dresden
11:45-12:15	Case studies of saltwater intrusion in Costa Rica	<b>Roberto Ramírez Chavarría</b> , PhD. Director of Research and Water Management, SENARA
12:15-12:45	Discussion	
12:45-13:45	<i>Lunch break</i>	
13:45-14:15	Climate scenarios and impacts of droughts and other hydrometeorological events in the Central American Dry Corridor	<b>Eric Alfaro Martínez</b> , PhD. Deputy Director of the Centre for Geophysical Research (CIGEFI), UCR. <b>Paula Pérez Briceño</b> , M.Sc. School of Geography, Sede Chorotega, UCR
14:15-14:45	Opportunities for managed aquifer recharge in Costa Rica	<b>José Pablo Bonilla Valverde</b> , PhD. AyA.
14:45-15:15	Transdisciplinary approach to complex water-related management: stakeholder assessment and analysis for Costa Rica	<b>Serena Caucci</b> , PhD. Researcher in Sanitation and the Water-Soil-Waste Nexus. Institute for Integrated Management of Material Fluxes and of Resources, United Nations University
15:15-15:35	<i>Coffee break</i>	
15:35-16:15	Discussion panel	
16:15-17:00	Conclusions	<b>Juan Carlos Picón Cruz</b> , PhD. Director CEMEDE-UNA, Sede Regional Chorotega <b>Pável Bautista Solís</b> , PhD. Researcher CEMEDE-UNA, Sede Regional Chorotega

# Annex 3 | Event photos





